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ORIGINAL ARTICLES.

I.—A Case of Metamorphism of Chalk.

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(PLATE V.)

CASES of metamorphosed limestones where the calcium carbonate has been converted by contact with some igneous magma into a calc-silicate rock are by no means rare, one of the best known being the conversion of the Coniston Limestone of the Lake District by the Shap Granite into a rock with various calc-silicate and other minerals such as Wollastonite, Omphacite, etc., as described by Messrs. Harker and Marr.[1] But as far as I know, no case has been recorded where ordinary white chalk has been similarly changed. Dr. Hibsch[2] describes a case of baculite marl containing Foraminifera which has been altered by contact with dolerite. The Foraminifera disappear and the rock becomes a granular limestone with epidote, forming a calc-silicate hornstone. This seems the nearest case to the alteration in co. Antrim I am about to describe.

As most geologists know, the Irish Chalk is considerably harder than the English variety, due, it is usually considered, to the baking action of the overlying basalts, although this idea is far from being generally accepted. In places it is not uncommon for dykes to have penetrated the chalk and to have altered it at the point of contact to crystalline limestone. Nearly a century ago Berger[3] stated that "the chalk is frequently traversed by basaltic dykes, and often undergoes a remarkable alteration at the point of contact. The change sometimes affects 10 to 12 feet from wall of dyke, gradually decreasing from the dyke. The extreme effect presents a dark-brown crystalline limestone, the crystals running in flakes as large as those of coarse primitive limestone, etc." Other instances of the disappearance of the organisms and the production of crystals of calcite could be quoted.

In 1904 Miss M. K. Andrews, of Belfast, while examining the

[1] Q.J.G.S., 1891.
[2] Verhandlungen Geol. Reichsanstalt, 1889, p. 204.
[3] Trans. G. S., vol. iii.

altered chalk at Scawt Hill, an old volcanic neck, about 6 miles north of Larne, came upon a dyke traversing the 'neck' dolerite of the hill and cutting across a narrow band of chalk. The geological structure of the district is that common to the basaltic plateau of Antrim, and consists of the basic lava-flows covering the Chalk and other Mesozoic beds, the chalk being the usual hard variety of Ireland. Of this hill the Irish Survey Memoir to Sheet 20 states that "at Slieve Scawt the Chalk has been carried up with the basaltic mass forming the volcanic neck. By igneous action it has been converted into a highly crystalline saccharoidal marble." Miss Andrews informs me that "the band of chalk appears to project horizontally into the 'neck'; and the dyke, which is between 3 and 4 feet wide, is running vertically through the 'neck' cutting across the tongue of chalk." The chalk had weathered so much that it was quite unexpectedly that she came upon the dyke. Miss Andrews obtained various samples from different points, and after having sections cut kindly handed them over to me. The specimens include (i) the rock forming the 'neck' and which she thinks has carried up the chalk; (ii) the dyke which runs through the neck; and (iii) the chalk in various stages of metamorphism.

Number I, may be dismissed very briefly, as it is one of the typical igneous rocks of the district, namely, a fine-grained ophitic dolerite. It is holocrystalline, the minerals being augite, felspar, olivine, and magnetite. The augite is in rather large pale-brown non-pleochroic crystals, broken up by longish lath-shaped crystals of plagioclase which appear to be labradorite. The olivine is roughly idiomorphic, generally clear and colourless, but changed to yellow serpentine along the cracks.

Number II (Pl. V, Fig. 1), the dyke, proves to be a very interesting rock. It is a granitoid, holocrystalline, basic rock, and may perhaps be best classed with Harker's "diabases without olivine," although its granitoid structure would almost lead one to call it a gabbro. Its most striking feature is its beautifully pleochroic augite, which is found in well-marked eight-sided crystals. These augites are apparently titaniferous, with a pleochroism varying from a dark lilac to yellowish green and frequently showing the hour-glass structure. They are well-zoned, and in some cases show undulating extinction, but in the majority of crystals, although there is a well-marked outer zone suggesting a different composition, it extinguishes at practically the same angle as the main mass of the crystal. The felspar has decomposed, and is filled with feathery and radiating decomposition products, so that it is not possible to distinguish the variety. No olivine was detected, but a little interstitial quartz was found, while apatite in small but well-marked prisms is fairly frequent. Iron-ores are also plentiful, the chief being magnetite, in places having a kind of reaction rim of actinolite (?); ilmenite is present, as is also pyrite.

The first noteworthy change in the chalk is seen in a section from 20 yards away from dyke. Here the organisms have disappeared, and the chalk has become finely granular owing to the development of fine crystals or grains of calcite. About two yards from dyke the chalk has become a typical crystalline limestone with large crystals of

calcite showing well-marked lamellar twinning and rhombohedral cleavage. One section shows small flakes of mica which are probably phlogopite.

Adjoining, and also caught up in, dyke is a rock which weathers so dark that it is difficult to tell it, except on a freshly fractured surface, from the dyke. It is found on microscopic examination to be the chalk completely altered into what may be termed a Calc-Silicate Hornstone, and specimens from different positions, while coming under this name, show different proportions of the minerals present. The size of the constituent crystals also varies from rather finely granular ones, mutually interfering, to larger well-marked crystals which are in places idiomorphic. The minerals found in the various specimens may be enumerated preparatory to a description of the rock. They are Wollastonite, Scapolite, Zoisite, Calcite, Diopside, Anorthite, and Magnetite. I strongly suspect Ilmenite as being present, but I could not prove it by chemical tests, while another mineral seen in sections as tiny, idiomorphic, octahedral, yellowish-brown, isotropic crystals is possibly Perofskite, but as I did not find it in the crushed rock I could not be certain of its identification. Garnets were specially looked for, but not detected, nor were any coloured minerals present such as Idocrase or Epidote.

The identification of the various minerals in the sections is by no means easy, as with the exception of the magnetite they are clear and colourless, and only in rare cases did they give figures in convergent light sufficiently good to obtain the sign. It was, however, obtained with most of the minerals, but specimens of the rock were also crushed, sieved, and separated by methylene iodide. Separation was also done, and the specific gravity of the minerals obtained, by means of the diffusion-column and confirmed by the refractive index, and in the case of diopside by the micro-chemical test for magnesium.

The first specimen examined is chiefly composed of two minerals, one of which is of a different refractive index from the other. Both are biaxial, and were found to be wollastonite and diopside. Further search revealed grains of a negative uniaxial mineral which proved to be scapolite. A little magnetite is scattered through the section, while anorthite is also present in small quantity. Another section from near the above shows crystals of a larger size, and in places crystals of calcite have enclosed idiomorphic crystals of other minerals in a poecilitic fashion (Pl. V, Fig. 3). These latter include long crystals, about three times as long as broad, of zoisite, having a rough cross parting, low polarization colours, and a high refractive index. They frequently show twinning in plane polarized light. Scapolite with a negative uniaxial figure, straight extinction, and moderately bright polarization colours is also to be seen with good crystal outlines, as is wollastonite with still brighter colours. Magnetite is scattered rather thickly throughout the section.

A third specimen is interesting as it shows a section of the rock with the magnetite almost absent from one half and thickly scattered over the other half (Pl. V, Fig. 2). All the above-mentioned minerals are present in some part of the section, but the grouping is very variable.

With regard to the cause of this particular alteration of the chalk, I cannot say much as I have not analysed specimens of the unaltered chalk. According to Hume's analyses,[1] the white limestone (Upper Chalk) that he analysed did not contain more than one per cent. of impurity, and this would not be enough to supply the silica in the metamorphosed rock. That the dyke supplied the heat necessary, that is, that the metamorphism took place subsequently to the formation of the 'neck,' I feel convinced, as the conversion of chalk into crystalline limestone is chiefly found in connection with dykes later than the chief outflow of lava over the county, and I can only suggest that there has been a mixture of the dyke with the chalk in different proportions. This would explain the varying mineral composition of the different specimens, the iron of the ferro-magnesian minerals being thrown out in the form of magnetite, the magnesium going to form the diopside. The parts where there was an abundance of magnetite would be those with the largest amount of mixture with the dyke.

In conclusion, I should like to thank Miss M. K. Andrews for the loan of sections and specimens, Drs. Cullis and Flett for advice and suggestions, and Mr. Waldron Griffiths, of Cirencester, for the micro-photographs illustrating this paper.

EXPLANATION OF PLATE V.

Fig. 1.—Diabase: Scawt Hill, co. Antrim. × 15. The zoning of the augites is well seen on the right in the two long crystals. The lighter part seen in the section is felspar; iron-ores are black and opaque, while apatite is seen in six-sided section.

Fig. 2.—Calc-silicate Hornstone: Scawt Hill. × 15. This shows the difference due to the varying amount of magnetite present and the sharp line marking off one part from the other.

Fig. 3.—Calc-silicate Hornstone: Scawt Hill. × 25. The idiomorphic character of some of the minerals is well seen near the centre of the section, where wollastonite, zoisite, and scapolite are enclosed by the clear calcite.

II.—Note on the Geological Age of the Shales of the Parys Mountain, Anglesey.

By G. J. Williams, M.I.M.E., Assoc. Inst. M.M., F.G.S.

THE rocks of the Parys Mountain, which lies about two miles to the south of the town of Amlwch in Anglesey, were described in 1878 by the late Mr. T. Fanning Evans, H.M. Inspector of Mines, who regarded the Parys Mountain "as an outlying piece of ground, geologically identical with the region in which the great slate-mines of Festiniog occur, and from which it differs only in being developed on a much smaller scale, and in being highly metalliferous."[2]

The Festiniog slate beds are well known to be of Llandeilo age, but at the time Mr. Evans wrote, thirty years ago, little was known of the black shales of North Wales or their fossil contents.

In the second edition of Ramsay's "Geology of North Wales," p. 248, reference is made to a band of very black shale containing

[1] Q.J.G.S., vol. liii (1897).

[2] Trans. Manchester Geol. Soc., vol. xiv (1878), p. 369.

Fig. 1.

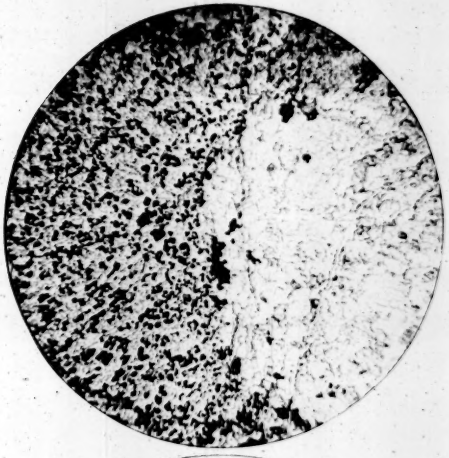


Fig. 2.

Fig. 3.

Metamorphism of Chalk : Scawt Hill, Co. Antrim.

graptolites, existing between the two principal hard bands of the Parys Mountain, but no list of species is given.

Professor McKenny Hughes, in his second paper on the Geology of Anglesey, refers to "the black shales between the two great felsite ribs" in the Mona Mines of the Parys Mountain as the highest horizon from which he had procured any fossils.[1] The late Mr. Fanning Evans, while searching for fossils in Prof. Hughes' company, "had the good luck to pick up a slab containing no less than eight species of graptolites," of which a list is given, but this appears to have been the only fossiliferous piece discovered.

On several occasions during the last dozen years I have searched for fossils in the shales, but succeeded in obtaining none other than obscure traces till January of last year, when I discovered a number of Llandovery species, and I found others during a visit in the month of May. At this time a tunnel was being driven south in a part of the Mona Mine, between the two "ribs" mentioned above, and it is from this tunnel that the graptolites were obtained. The beds in the tunnel, which is now about sixty yards long, dip generally at an angle of about 45° north, though there occur some contortions and faults. The rocks consist of soft earthy shales, more sandy beds, and a few lenticular bands of a fine-grained, extremely hard rock. In the softer beds the graptolites are but indifferently preserved, while from the more sandy ones many specimens were obtained beautifully preserved in relief. The following is a list of the species which were kindly named for me by Miss Elles, D.Sc.:—

Cephalograptus cometa, Gein.
Climacograptus Torquisti, Elles & Wood.
Climacograptus sp.?
Diplograptus tamariscus, Nich.
D. sinuatus, Nich.
Monograptus Becki, Lapw.
M. Clingani, Carr.
M. communis, Lapw.
M. convolutus, His.
M. involutus, Lapw.
M. jaculum, Lapw.
M. leptotheca, Lapw.
M. lobiferus, McCoy.
,, ,, *M.* aff. *cyphus*, Lapw.
,, ,, var. *ambiguus*, Tornq.
Petalograptus minor, Elles.
P. palmeus, var. *latus*, Barr.

Miss Elles determines the zone as that of *Monograptus convolutus* (His.), just below the zone of *M. Sedgwickii* (Portl.).

Last August my friend Mr. Edward Greenly, F.G.S., who, as is well known, is making an exhaustive survey of the geology of Anglesey, collected specimens which came from the same tunnel, but farther south, and he kindly allows me to publish a list of the species he obtained, and which, like mine, were named by Miss Elles. They are the following:—

Climacograptus scalaris, His.
Monograptus discretus, Nich.
M. intermedius, Lapw.
M. Sedgwickii, Portl.

and one if not two species of *Diplograptus* which Miss Elles regards as new, and which will be described in the "Monograph of British Graptolites." Mr. Greenly's specimens are from a slightly higher horizon than mine, viz. that of *M. Sedgwickii*, so that in the beds cut through in the tunnel the dip is inverted or there is a downthrow to the south.

[1] T. McKenny Hughes, "On the Geology of Anglesey," No. 2: Q.J.G.S., vol. xxxviii (1882), p. 27.

Mr. Greenly informs me that he has lately obtained some graptolites of the 'tuning-fork' type a mile or two away on the strike of the Parys Mountain, thus indicating a much lower horizon not far distant.

It is interesting to note that the copper ore of the Parys Mountain, like the lead and zinc ores of Cardiganshire and Montgomeryshire, occur in beds of Llandovery age.

My best thanks are due to Miss Elles for so kindly identifying the graptolites and for her remarks concerning their zonal value.

III.—The Selbornian of Stonebarrow Cliff, Charmouth.

By W. D. Lang, M.A., F.G.S., F.Z.S., of the British Museum (Natural History).

I. *Introductory.*

ALTHOUGH the succession of Cretaceous beds on Black Ven is well known and much has been written on the various members of the series, only cursory references have been made to those on Stonebarrow Cliff on the east of Charmouth, and the lower beds have never been recorded therefrom. A full list of the literature on the geology of this district, including all that has been written on the Selbornian, is given in the Survey Memoir[1] on the "Geology of Sidmouth and Lyme Regis" and another bibliography in the account of the last excursion to Lyme by the Geologists' Association.[2]

The only mention of the lower beds of the Selbornian (i.e. the zone of *Hoplites interruptus*) on Stonebarrow among these papers is that by Jukes-Browne on the Vale of Marshwood[3]: "Taking next a traverse through the southern outliers near the coast, we find the Cretaceous base-line in Black Ven Cliff at about 320 feet above the sea. Thence it rises to about 350 feet in Stone Barrow, and 400 and more on Golden Cap and Langdon Hill, and finally to about 500 feet on Eype Down." But since, two years later,[4] Jukes-Browne, having described the Gault on Golden Cap, says, "the next cliff exposure is in the face of Black Ven," it is reasonable to suppose that he never found the base of the Cretaceous on Stonebarrow, and that his 350 feet is only an estimate. This point is mentioned because here, although it is not claimed that the heights given are other than approximate, the base of the Cretaceous is estimated only at 320 feet, a very little higher than the height given on Black Ven.[5] The reason for this low estimate will be given later. The exact height, however, is of small importance; moreover, it is possible that the whole cliff face in the neighbourhood of the sections may have undergone some slipping and so have made the Gault appear lower than it really is.

It is not surprising if the Gault on Stonebarrow has not been sought with enthusiasm; for the parts of the cliff where it occurs have suffered

[1] H. B. Woodward: "Geology of Sidmouth and Lyme Regis," 1906, pp. 86–88.

[2] Proc. Geol. Assoc., vol. xix (1906), p. 340.

[3] A. J. Jukes-Browne: Proc. Dorset Nat. Hist. Club, vol. xviii (1897), p. 176; Geol. Mag., 1898, p. 164.

[4] A. J. Jukes-Browne, "Gault and Upper Greensand of England," 1900, p. 185: Mem. Geol. Survey.

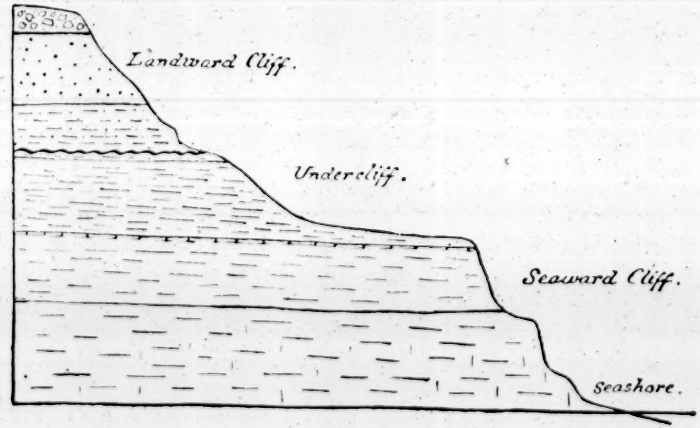
[5] W. D. Lang, "The Zone of *Hoplites interruptus* at Black Ven": Geol. Mag., 1904, p. 125.

FIG. 1.—GENERAL PROFILE SECTION OF STONEBARROW CLIFF.

This is drawn so as to be exactly comparable with the general section of Black Ven (GEOL. MAG., 1904, p. 127). In both cases the zonal boundaries in the Lias are taken from information in the Survey Memoir (H. B. Woodward, 1893, "Lias of England and Wales"), not from the author's observations.

North. South.

			Height in feet above sea-level.
SILURIAN.	Remains of zone of *Pecten asper*.	Weathered remains of Chert Beds.	450
	Zone of *Schlœnbachia rostrata*.	Foxmould without Cowstones in lower part.	350
	Zone of *Hoplites interruptus*.	Black Loams.	320
LIAS.	Zone of *Amaltheus margaritatus*.	Loams and Calcareous Sandstone.	300
	Zone of *Liparoceras capricornus*.	Green Ammonite Beds.	
	Zones of *Amaltheus ibex*, *Uptonia jamesoni*, *Deroceras armatum*.	Belemnite Marls.	200
	Zones of *Echioceras raricostatum*, *Oxynoticeras oxynotus*, *Asteroceras obtusum*.	Blue Marls and Limestones.	120
			0



from great slips and are much overgrown, forming an undercliff of great beauty but offering small hope of exposures. This undercliff, known as Fairy Dell or Cain's Folly, is about 200 yards across at its widest part and some half a mile long; it rises about 100–200 feet from its seaward to its landward margin. It is composed (see Fig. 1) of the upper part of the *capricornus* and of the lower part of the *margaritatus* zones of the Lias and of the lowest beds of the Gault. The actual junction of the Gault with the Lias has not yet been found on Stonebarrow. The seaward margin of the undercliff tops cliffs about 200 feet in height of Lias clays, marls, and limestones, from the *capricornus* down to the *obtusus* zone. Landwards it is backed by Greensand cliffs rising more than 100 feet above the Dell at their highest point.

If the Dell be entered by the footpath leading to it from Charmouth it will be found that the path makes a steep descent of the landward Greensand cliff, and has fallen away before it reaches comparatively level ground. A few yards east of this spot a small bluff is reached, eastward of which the cliff trends more inland. The bluff descends into a small swamp, and the footpath skirts the seaward edge of this. The base of the landward cliff just west of the bluff shows a small section in the Gault. On the eastern side of the bluff, where the landward cliff begins to trend away from the sea, the Gault is again exposed, and is seen to pass upwards into Foxmould sand before the section is broken.

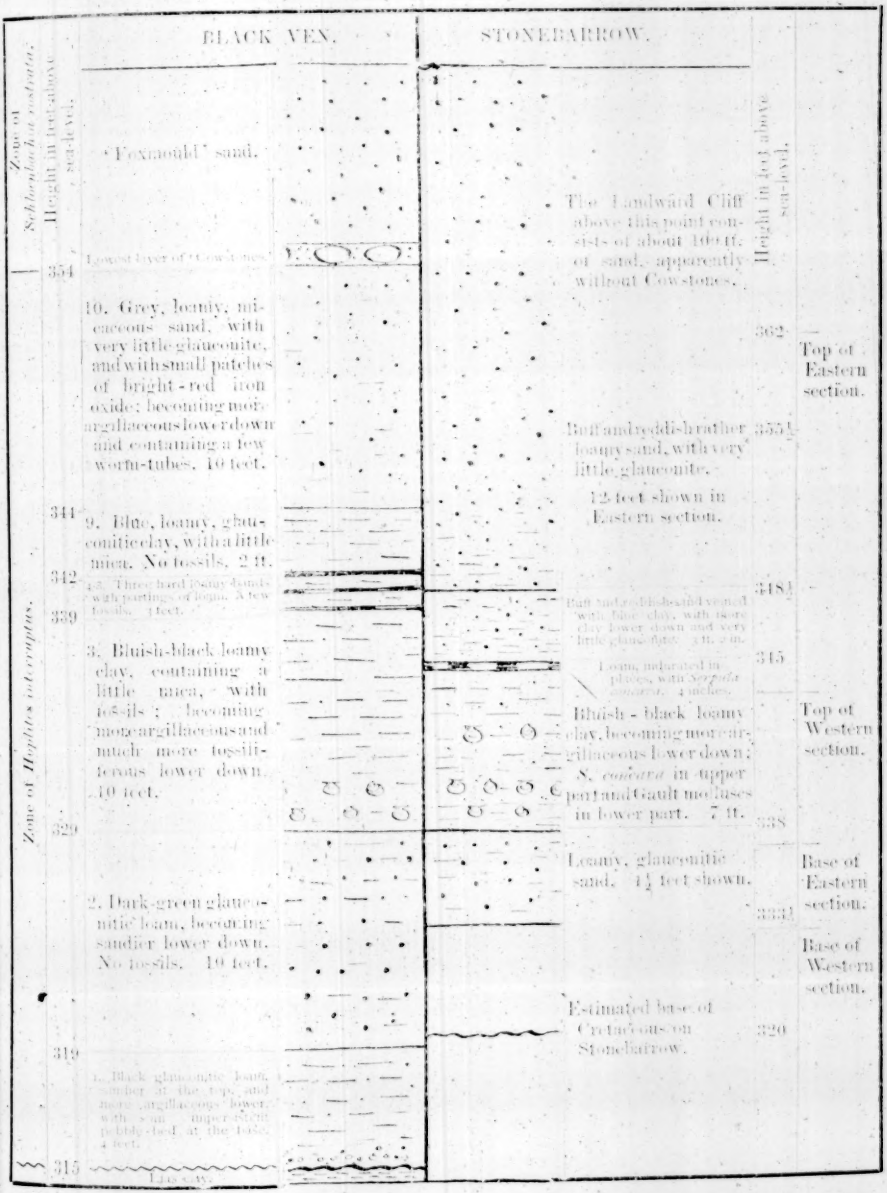
II. *The Western Gault Section.*

The western section is about 10 feet in extent. It is terminated above by a capping of fallen Greensand forming a small grass-covered flat on the general slope of the landward cliff. Two beds are to be recognized (see Fig. 2); the upper 7 feet are composed of bluish-black loamy clay containing Gault fossils of the same kinds as those found in Bed 3 on Black Ven, more being found at the bottom than at the top. This gives way below to a non-fossiliferous loamy, glauconitic sand, which is very soon hidden by talus. No alteration was observed on following it down for a foot or so by digging through the talus. The talus slope ends in the swampy ground already mentioned, which is nearly level with the footpath. The 300-feet contour-line on the 6-inch Ordnance map comes very close to the footpath; and since the descent here is very slight, cannot be more than 15 feet below it. Allowing about 20 feet for the talus slope and the swamp between this and the footpath, the base of the section would be at the height of about 334 feet, and the base of Bed 3 with the Gault fossils 338 feet.

III. *The Bluff between the Sections.*

The little bluff between the eastern and western sections is composed of bluish-black loam hidden under a wet matting of sandy soil washed down from above and bound by algæ and other plants into a tough felt. If this is peeled off the loam can be examined; but the examination proved unsatisfactory owing to the dripping state of the bluff and the bog at the bottom. No fossils were found in it and its horizon was not determined.

FIG. 2. Diagram of the Zone of *Hoplites interruptus* and the base of the Zone of *Schlænbachia rostrata* on Black Ven and on Stonebarrow, to show correlation.


BLACK VEN.
STONEBARROW.
Zone of Schlænbachia rostrata.
Zone of Hoplites interruptus.
Height in feet above sea-level.
'Foxmould' sand.
Lowest layer of rt. cowstones.
354
10. Grey, loamy, micaceous sand, with very little glauconite, and with small patches of bright-red iron oxide; becoming more argillaceous lower down and containing a few worm-tubes. 10 feet.
341
9. Blue, loamy, glauconitic clay, with a little mica. No fossils. 2 ft.
342
8. Three hard loamy bands with partings of loam. A few fossils. 1 feet.
339
3. Bluish-black loamy clay, containing a little mica, with fossils; becoming more argillaceous and much more fossiliferous lower down. 10 feet.
329
2. Dark-green glauconitic loam, becoming sandier lower down. No fossils. 10 feet.
319
1. Black glauconitic loam, sandier at the top, and more argillaceous lower, with a thin impersistent pebble-bed at the base. 4 feet.
315
Lias.
The Landward Cliff above this point consists of about 100 ft. of sand, apparently without Cowstones.
362
Top of Eastern section.
Buff and reddish-brown loamy sand, with very little glauconite.
12 feet shown in Eastern section.
355½
Buff and reddish-brown sand with blue clay, with more clay lower down and very little glauconite. 3 ft. 3 in.
348½
Loam, indurated in places, with *Serpula* [illegible] 4 inches.
345
Top of Western section.
Bluish-black loamy clay, becoming more argillaceous lower down; *S. cultrata* in upper part and Gault moulages in lower part. 7 ft.
338
Loamy, glauconitic sand. 1½ feet shown.
333½
Base of Eastern section.
Base of Western section.
Estimated base of Cretaceous on Stonebarrow.
320

IV. *The Eastern Gault Section.*

On the eastern side of the bluff another section is seen in the Gault, which passes upwards into Foxmould. At the base occurs bluish-black loam with Gault fossils, and a little digging through the talus below exposes a junction with glauconitic loamy sand. These are obviously the two beds exposed in the western section. The blue loam becomes sandier on being traced upwards, and the fossils become scarcer, except that many *Serpula concava*, Sowerby, occur in the higher part. About 7 feet from the bottom of the section (see Fig. 2) an impersistent band of hardened loam containing *S. concava*, Sowerby, is found; above which the beds become quite sandy, with blue or grey argillaceous veins, for about 4 feet, and then pass into typical Foxmould sand.

In the right-hand half of Fig. 2 the two sections are represented combined in a diagram. The respective tops and bases of the two sections are marked on the right-hand margin.

The fossils recognised from the blue loam besides *S. concava*, Sowerby, were *Inoceramus concentricus*, Parkinson, *Lima gaultina*, Woods,[1] *Pecten* (*Syncyclonema*) *orbicularis*, Sowerby, *Pinna Robinaldina*, d'Orbigny,[2] *Grammatoceras* [*Arca*] *carinatus* (Sow.), *Pholadomya* sp., and *Corbula* sp.

V. *Comparison with the Corresponding Beds on Black Ven and on Golden Cap.* (Figs. 2 and 3.)

On the left-hand side of Fig. 2 is a diagram of the Gault beds on Black Ven, combining the two sections described in the Geological Magazine for 1904.[3] Beds 2 and 3 of that section exactly correspond with the two lowest beds exposed on Stonebarrow, and since the fossil contents at the base of the higher beds are the same in each case it follows that they are on the same stratigraphical horizon. Now on Golden Cap, which lies two miles to the east of Stonebarrow (Black Ven is a mile and a third to the west of that cliff), the only account of the Gault is that by Jukes-Browne in the Survey Memoir.[4] In the section here described the same bed is distinguishable, consisting of dark loam with Gault fossils at the base, resting on a glauconitic sand. There is thus a stratigraphical datum-line on all three cliffs from which attempts at correlation of all the beds can be started.

On Black Ven, at about 25 feet above the Gault fossils, appears the lowest layer of Cowstones. And this has been taken as the base of the zone of *Schlenbachia rostrata*. But on Stonebarrow no Cowstones have been recorded. The landward cliff above the sections described is a steep slope of Foxmould sands capped by broken remains of the Chert-beds and of higher Cretaceous horizons. Here and there a section is shown, but the whole surface is much disturbed by fallen material and innumerable rabbit-burrows. Were Cowstones present they should not be hard to find, for owing to their hardness they stand out imminent from the section on Black Ven, and lie fallen in numbers in the boggy land beneath.

[1] Hitherto recorded from the Gault of this district as *Lima parallela*. See Woods, "Cretaceous Lamellibranchs," vol. ii (1904), pp. 31 and 32: Mon. Pal. Soc.

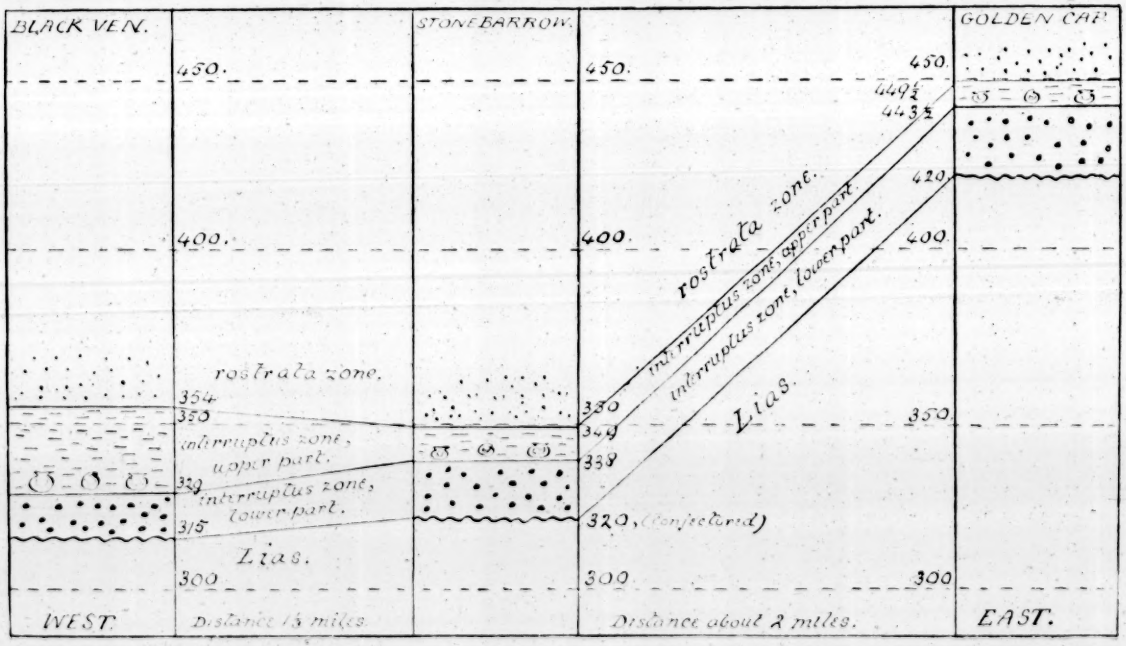
[2] Hitherto recorded from the Gault of this district as *Pinna tetragona* or *P. subtetragona*. See Woods, loc. cit., 1906, p. 98.

[3] W. D. Lang, loc. cit.: Geol. Mag., 1904, pp. 125 and 130.

[4] A. J. Jukes-Browne, "Gault and Upper Greensand of England," 1900, pp. 184 and 185: Mem. Geol. Surv.

Fig. 3.—Diagram to show the variations in the thickness of the upper and lower parts of the zone of *Hoplites interruptus* on Black Ven, Stonebarrow, and Golden Cap.

The numbers in the diagram represent the approximate number of feet above sea-level.



In the absence of Cowstones it is impossible to draw the lithological limit between the zones of *Hoplites interruptus* and of *Schloenbachia rostrata* that is recognized on Black Ven. In the absence of fossils the true limit cannot be determined. If the point at which typical Foxmould sand begins is taken as the lower limit of the *rostrata* zone, it is obvious (see Fig. 2) that the *interruptus* zone is thinner on Stonebarrow than on Black Ven. Again, on Golden Cap, Jukes-Browne describes some 100 feet of sand (and no Cowstones are mentioned) resting directly on the Gault fossil bed, which is only 6 feet thick. That is, if lithological characters are taken into consideration in the absence of fossil evidence, the *interruptus* zone *above* Bed 3 has thinned from 25 feet on Black Ven to 11 feet on Stonebarrow and 6 feet on Golden Cap.

If fossils occurred it might be found that the zone had not thinned from west to east, but only become more sandy. But the evidence of the hard bands (Beds 4, 6, and 8) on Black Ven is against this supposition. For it looks as if the 4 inches of loam, indurated in places, containing *Serpula concava*, Sowerby, on Stonebarrow, was the equivalent of these hard bands on Black Ven. In that case Bed 3 on Stonebarrow would be 7 feet thick, against 10 feet on Black Ven; thus showing a thinning of the upper part of the zone eastwards.

The lower part of the zone remains to be considered. On Black Ven, beneath Bed 3, there are about 14 feet of loamy sand before the junction with the Lias is seen. On Stonebarrow the junction has not been found, and only a foot or two of loamy glauconitic sand is shown beneath Bed 3. On Golden Cap about 24 feet, chiefly of sands, are exposed beneath Bed 3, according to the interpretation here given to Jukes-Browne's section. It is probable, then, that the *interruptus* zone below Bed 3 thins from east to west, in the contrary direction to the upper part of the zone. Assuming that this thinning is regular, and taking two miles as the distance between the Golden Cap and Stonebarrow sections, and one and a third miles as that between the Stonebarrow and Black Ven sections, the thickness on Stonebarrow below Bed 3 would be 18 feet. This would make the base of the Cretaceous on Stonebarrow 320 feet above sea-level.

VI. *Summary and Conclusions.*

The chief results arrived at in this paper may be summarized as follows:—

1. The *Hoplites interruptus* zone is exposed in two small sections on Stonebarrow cliff, but the junction with the Lias has not been found.

2. A fossil bed containing the *interruptus* zone fauna occurs here, westwards on Black Ven and eastwards on Golden Cap, thus giving a stratigraphical datum-line.

3. That part of the zone above this fossil bed either becomes more sandy when traced from west to east, or, more probably, begins to thin out.

4. That part of the zone below this fossil bed thickens from west to east.

5. No Cowstones appear on Stonebarrow, nor have they been recorded from Golden Cap.

IV.—Titaniferous Volcanic Rocks.

By T. Crook, A.R.C.Sc.I., F.G.S.

IN a paper read recently at a meeting of the Geological Society, Dr. Washington proposes to treat certain basalts of the Western Mediterranean basin as constituting "a hitherto unrecognised petrographic province, or comagmatic region, one of the most salient characters of which is the presence of salfemanes (basalts) that contain remarkably high amounts of titanium."[1]

He records the results of fourteen analyses. Of the specimens analysed, four are from Catalonia in Eastern Spain, four from Sardinia, and six from the two small islands of Pantelleria and Linosa. The results show a silica percentage varying from 44 to 52, alumina from 12 to 16, magnesia from 4·4 to 10·8. The titanium dioxide varies from 2·64 to 6·88 per cent. in the fourteen analyses given, with an average of 4·3 per cent. It should be pointed out that two of Dr. Washington's Pantelleria specimens were not collected by himself, and the specimen having the maximum content of titanium dioxide (6·88 per cent.) was bought from a mineral dealer. Phosphorus pentoxide is also abundant, but here again the maximum value (2·14 per cent.), which is in the mineral dealer's specimen, somewhat overshadows the rest. With regard to the figures for titanium dioxide, the Catalonia specimens show an average percentage of 4·33, those of Sardinia 3·26, Linosa 3·70, and Pantelleria 5·73. These figures, as far as they go, indicate a somewhat irregular distribution of titanium, with excessive segregation in Pantelleria.

The only earlier worker recognised by Dr. Washington as having noted the highly titaniferous character of certain basalts in the Western Mediterranean area is Dr. Förstner, who, as recently as 1891, found over 5 per cent. of titanium dioxide in a Pantelleria basalt. He appears to be unaware of the much earlier work done by Cordier, a conspicuous member of that little band of French workers, with whose collective labours on the structure and mineral composition of volcanic rocks, the science of petrography may be said to begin.

Among a large number of contributions made by Cordier to mineralogy and geology, three dealing with volcanic rocks are of special petrographical interest and value. These are as follows:—

1. "Recherches sur différens produits volcaniques": Journal des Mines, vol. xxi, No. 124, 1807.
2. "De la manière d'être du Fer titané dans les roches volcaniques, et du rôle qu'y joue ce minéral": Journal des Mines, vol. xxiii, No. 133, 1808.
3. "Mémoire sur les substances minérales dites en masse, qui entrent dans la composition des roches volcaniques de tous les âges": Journal de Physique, vols. lxxxii and lxxxiii, 1816.

The last-mentioned contribution is familiar. It has been excellently summarized and appreciated by Professor Cole (see *Aids in Practical Geology*). The first two appear not to be so well known. Their

[1] Dr. H. S. Washington, "The Titaniferous Basalts of the Western Mediterranean: a preliminary notice": Quart. Journ. Geol. Soc., vol. lxiii (1907), No. 249.

interest and importance were, however, fully recognised by Haüy and other early mineralogists; but they find no place in the bibliography of Fouqué & Lévy's *Minéralogie Micrographique*, and they have not been adequately appreciated by modern writers on petrography.

Since these three memoirs constitute a 'suite,' and as each forms part of a definite scheme of work by Cordier on the subject of volcanic rocks, it seems desirable that memoirs 1 and 2 should be summarized, especially as their main purport has an important bearing on the petrographic work dealt with in Dr. Washington's preliminary notice.

Memoir No. 1.

This embodies the results of the examination of a large number of black magnetic sands, obtained from river beds, and lake and sea shores, in the vicinity of volcanoes. Cordier regarded the sands as the disintegration products of the volcanic rocks with which they were associated. They were noted as being sufficiently abundant on certain beaches to tempt people to use them as iron-ore. They were rarely pure (presumably as iron-ore), being usually mixed with grains of many other minerals, including felspar, mica, pyroxene, amphibole, melanite (grenat noir), and leucite (amphigène), while sometimes corundum, zircon, spinel, and sphene (titane siliceo-calcaire) were present.

The highly magnetic portion of the sand was separated from the rest by means of a bar magnet, and it was submitted to special examination, including chemical analysis. The portion thus withdrawn was described as being strongly magnetic, some of the grains exhibiting polarity. Their specific gravity varied from 4·59 to 4·89, and in nearly all their physical characters they differed from ordinary magnetite (fer oxydulé), with which, up to that time, they had been confused.

He showed by analysis that these black highly magnetic grains contained a variable but fairly high percentage of titanium, and gave the following analyses:—

	Niedermennich.	Teneriffe.	Puy.
Oxide of iron ...	79·0	79·2	82·0
Oxide of titanium ...	15·9	14·8	12·6
Oxide of manganese ...	2·6	1·6	4·5
Alumina ...	1·0	0·8	0·6
Chromic acid ...	—	—	traces

We need not here discuss the merit of these analyses, except to point out that, in their essential features, they may reasonably be regarded as being fairly correct. Perhaps the most interesting feature is that chromium sesquioxide was observed to occur in traces, and it is not unlikely that this occurred as an isomorphous intergrowth of chromium spinel with magnetite.

Cordier examined, altogether, 27 samples of sand from the volcanic rocks of ten different countries. His localities include Central France, Eastern Spain, the Rhine, Rome, Vesuvius, Etna, and St. Pierre (Martinique). In no case did he find titanium oxide to be absent from the highly magnetic constituent; the amount was variable, but did not exceed 16 per cent. He concluded that this mineral was

the same in all cases; that it was a compound of iron and titanium oxides; and he gave it the name *fer titané*. We need not here concern ourselves with the misfortune that befel the use of Cordier's term. It is sufficient for us to note that his *fer titané* is the same thing as our modern titaniferous magnetite (*titanomagnétite* of Lacroix); while the *fer titané* of modern French is the mineral ilmenite.

Memoir No. 2.

Having examined the sands, Cordier proceeded to work on the volcanic rocks themselves, and here again he examined material from many different sources. He first attempted to isolate the titaniferous magnetite by crushing and magnetic separation; but he observed that a considerable amount was always left behind, which could not be withdrawn in this way.[1] For this reason, he resorted to the method of leaching the titaniferous magnetite from the crushed rock by means of hydrochloric acid.

A large number of basalts, ashes, and tuffs, from Puy-de-Dôme, Vesuvius, Etna, Teneriffe, Popayan (South America), and elsewhere, were examined in this way, and analysis showed a variation from 0·5 to 4 per cent. in their titanium oxide content.

Cordier expressed surprise that titanium should be so widely distributed in volcanic rocks, and added that the only specimens which were practically free from it were those of certain pumices and glassy lavas. He estimated that 95 per cent. of volcanic rocks contained titaniferous magnetite in considerable amount, the proportion varying from 2 to 18 per cent. Its partial extraction, even when fine-grained and imperceptible to the eye, could be accomplished easily by crushing and separation with a bar magnet. Volcanic rocks owed their magnetic character exclusively to this mineral, except when hæmatite was present, which was very rarely. Its abundance in these rocks fully explained its plentiful occurrence in the sands which were derived from them by disintegration.

It is unnecessary to refer to Cordier's third and well-known memoir of 1815, except to note that in it he continues to use the name *fer titané* for the highly magnetic constituents of volcanic rocks. He distinguished this mineral from ilmenite, stating that the latter consisted of a combination of titanium and iron oxides in somewhat equal proportions, whereas *fer titané* contained only about 15 per cent. of titanium oxide. He was also aware that ilmenite was far less magnetic than titaniferous magnetite, and that with proper care it remained behind when the latter was extracted by the magnet. He found only a small quantity of ilmenite, as such, in the volcanic rocks which he examined.

There are many points arising out of Cordier's results which it might be profitable to discuss, did space permit. One point is especially worthy of emphasis, and that is the importance, in this

[1] Cordier appears to have thought that this was due to the extreme fineness of some of the particles, and the difficulty of freeing them from the matrix. It is not unlikely, however, that some of the grains which thus resisted attraction were ilmenite.

particular case, of the simple process of crushing and magnetic separation as a means of distinguishing titaniferous magnetite from ilmenite, when these occur in rocks. It has been commonly considered that if leucoxene is developed among the cleavage cracks the mineral must be ilmenite. But it should be remembered that titaniferous magnetite also yields leucoxene as an alteration product; and it may on this account be safely asserted, that much titaniferous magnetite has been described as ilmenite on evidence gathered from rock sections alone. This confusion can be readily avoided by following Cordier's method of partially crushing the rock. It is convenient to sift, wash away the powder, and dry the residual grains. From these, magnetite, if present, can be withdrawn by a small hand magnet, whereas the ilmenite remains behind. The magnetite thus withdrawn is somewhat readily soluble in strong hot hydrochloric acid, and if the magnetite is titaniferous this can be proved chemically by the violet colour reaction on reduction with metallic tin.[1] In view of the simplicity and effectiveness of this process, Dr. Washington should have no difficulty in determining whether the titanium of his rocks is present as titanite, ilmenite, augite, olivine, or titaniferous magnetite. The matter is still under investigation, but Dr. Washington informs us that "the available data indicate that a large proportion of it is present in titaniferous magnetite, with probably somewhat less in the augite." On this matter we may venture to predict that further work will prove practically all the titanium to be present as titaniferous magnetite (and ilmenite), as Cordier showed about a hundred years ago.

Now that we have attempted to do justice to Cordier, let us proceed to examine certain features of Dr. Washington's preliminary notice which seem to call for criticism.

On page 76 (loc. cit.) we are told that "the pale green or colourless augites of Central Italy are markedly titaniferous," one of them carrying 2·85 per cent. of titanium dioxide. On looking up the account given by Dr. Washington in "The Roman Comagmatic Region" to which he refers us, we find that the titanium-dioxide content of this augite was determined in the following manner:—"The rock powder used for the chemical analysis of the rock was digested for some hours in warm dilute hydrochloric acid, to which a little hydrofluoric acid was added. The residue was washed out with dilute solution of sodium carbonate, and the process repeated, but without hydrofluoric acid, the final residue being, of course, washed perfectly free from all soluble salts. This process would naturally dissolve all the leucite, olivine, melilite, magnetite, apatite, and anorthite, which are the only other minerals present, and would have only a slight effect on the augite, removing the outer portions." Then follows an analysis which shows 2·85 per cent. of titanium dioxide.

The obvious defect of this procedure is, that ilmenite and rutile may easily have been present in the powder analysed. It is a fact that

[1] The possible occurrence of coarse intergrowths of ilmenite should always be kept in mind, and any residue which may be obtained should be examined magnetically, microscopically, and chemically, as rutile may also possibly be present.

rutile and ilmenite both occur as intergrowths with magnetite, and it is not at all uncommon for titaniferous magnetite to leave a residue of rutile when crushed and leached with strong hot hydrochloric acid. Therefore, unless it can be proved that ilmenite and rutile were absent, Dr. Washington's analysis of the above-mentioned rock residue does not prove that the titanium dioxide was present as titaniferous augite.

As regards the Linosa hornblende, which "yielded as much as 8·47 per cent. of titanium-dioxide," we need evidence that no inclusions of ilmenite, etc., were present in the crystal analysed. Indeed, some of the evidence so far adduced by various workers to support the view that titanium enters vitally and in any serious quantity into the composition of ordinary ferromagnesian minerals, is not at all convincing in its character.

Again, on page 73 (loc. cit.) Dr. Washington makes the following statement concerning the Western Mediterranean basalts and their titanium content: "Of the minor constituents, titanium-dioxide is the most notable. This constituent is present in every case in very large amounts: large, that is, for this substance, the average amount of which in igneous rocks is 1 per cent. or less. Indeed, the higher figures found in the table are unparalleled elsewhere, except in titaniferous ores."

Now considering the fact that titanium dioxide is more abundant in basic than in acid igneous rocks, we may reasonably contend that the Western Mediterranean basalts should be compared with other basalts, rather than with rocks in general, if we wish to understand the correct bearing of any peculiarity which they may exhibit with respect to their titanium content. While it may be true that igneous rocks in general do not average more than 1 per cent. of titanium dioxide, this statement is not true of the salfemane class, and it is still less true of certain yet more basic types.

In order to test this point fairly, let us take the analyses of the rocks of the salfemane class given in Dr. Washington's valuable compilation of rock analyses.[1] Of the 230 superior analyses of salfemanes there given, in which titanium dioxide was actually estimated, these rocks show a range from 0·03 to 6·18 per cent. of that oxide, with an average of about 1·67 per cent. Of these 230 salfemanes, 75 have more than 2 per cent. of titanium dioxide, 33 have over 3 per cent., while 16 have more than 4 per cent., and several have more than 5 per cent.

Further, Dr. Washington gives in his list of superior analyses, five taken from the results obtained by Grubenmann for the melilite-basalts of Baden. Of these five analyses, one is included in the salfemanes and four in the dofemanes; they range from 4·79 to 8·85 per cent. of titanium dioxide.

Instances could be multiplied to show the abundance of titanium in certain basic igneous rocks which are not 'titaniferous ores.' Indeed, the abundance of titaniferous ores themselves as segregations in igneous rocks is sufficient to make any one pause before giving assent to Dr. Washington's proposition, that the percentage of titanium dioxide

[1] "Chemical Analyses of Igneous Rocks": Professional Paper, No. 14, U.S. Geol. Survey, 1903.

in the rocks of any region should be made a fundamental feature in characterising a petrographic province. At any rate, his statement that "the higher figures found in the table are unparalleled elsewhere, except in titaniferous ores," seems not to be in accordance with facts.

Another feature of Dr. Washington's preliminary notice appears to make a somewhat heavy demand upon our credence. The analyses recorded, as already mentioned, are of specimens from only four localities, two of which are small adjacent islands, but the other localities are widely separated; and we are asked to regard these few analyses of certain widely separated rocks as indicative of a condition prevailing throughout that portion of the Western Mediterranean region which he has partially defined.

In this connection, one important fact already mentioned should be specially emphasised, and that is, that no mineral exhibits a more pronounced tendency to segregation than does titanic iron-ore. That such is the case has been abundantly proved. In some cases, whole mountains are practically built up of material which has been segregated in this way. Such segregated titanic ores are usually local, and their occurrence is significant as indicating that titanium dioxide has an irregular distribution in rock magmas, using the term magma in a broad regional sense. Even the method of sampling would appear to be an insufficient correction for such an irregular distribution, as the segregations are likely to be either too prominent or altogether beyond observation.

This brings us to the important question: What are the criteria of a comagmatic region? If such criteria are to be scientific rather than merely empirical, it would appear important that they should be based essentially on features of somewhat persistent and uniform development. In this respect, varying amounts of constituents such as alkalies may be admitted to a high place as criteria, for not only do they seriously affect the constitution and physical properties of essential minerals; they are also partly responsible for the production of a characteristic group of minerals of great importance, and they have a somewhat uniform distribution.

But the same claim can scarcely be urged for titanium dioxide, since it separates early, is liable to segregation, and does not vitally affect the chemical constitution and physical properties of any important group of the minerals according to which rocks are classified. It remains to be seen whether further work in the Western Mediterranean area will justify the use of titanium dioxide as the principal index of a special province. The evidence so far presented is far from being conclusive. It would appear that Dr. Washington has laid too much stress on the significance of the titanium content of the few rocks he has so far analysed, and it remains to be demonstrated whether even these are typical, for the area is a large one. Further, it is a well-known fact that the estimation of titanium is a matter of considerable difficulty, and even where it has not been altogether neglected the stated percentage is often untrustworthy, being in many cases probably much too low. This fact adds considerably to the necessity of exercising caution in arguing from a comparison with hitherto published analyses.

Again, we may call attention to the fact that Grubenmann found as much as 3 per cent. of chromium sesquioxide in the highly titaniferous-melilite basalts of Baden. It seems that this constituent has not been determined in the Western Mediterranean basalts, in spite of the fact that they also might be expected to contain chromium.

Chlorine, too, finds no place in the table of analyses, even among the undetermined constituents, although the norms for the fourteen specimens analysed exhibit an average of about 2 per cent. of apatite, and one norm shows the unusual amount of 5·04 per cent. of that mineral. Dr. Washington informs us that chlorine is present in some of the Linosa rocks, but its amount has not been estimated, and it is regarded as being derived from sea-water. One might have thought, however, that such quantities of apatite would have rendered it necessary to provide a place for chlorine (or fluorine) in stating the results of a first-rate analysis; and there are other reasons why the estimation of chlorine in such rocks should not be disregarded. In point of quantity, at any rate, it is likely to be of as much importance as nickel oxide, for which a place is provided.

On the whole, these Western Mediterranean basalts are very similar to one another, and such important chemical differences as they exhibit are abundantly manifest in their mineral composition. Indeed, their essential similarity is so striking that one is surprised to find these rocks described under names so various as Monchiquose, Camptonose, Limburgose, Andose, Akerose, and Andose-Camptonose. It may be necessary, as a matter of convenience, to give names to rocks, but such a multiplication of names is neither necessary nor useful. Such names only conceal the truth, and lead people to believe that the evidence at present available for rock classification is of a higher order of exactness than it really is. The plain fact of the matter is that, just as in biology the process of evolution to some extent defies the wisdom of the systematist, so in petrology the processes of differentiation and admixture confound his artifices. Dr. Evans has recently shown that the American system has not escaped from confusion.[1]

Such being the case, it is interesting to note the new turn that has been given to petrology by the study of the physico-chemical laws which underlie the process of differentiation. A fuller knowledge of these laws will probably emphasise the significance of the mineral composition of rocks as an index to chemical conditions. When these laws have been worked out, it is not unlikely that mineralogical methods (including chemical analysis as a subsidiary feature) will meet the full demand which a natural-history study of rock relationships makes upon them. Such an issue would be welcome, as it would simplify rather than complicate the problem of classification; at any rate, it would render unnecessary the unnatural system and unwieldy terminology which the Americans have introduced.

In conclusion, we may be excused for emphasising the fact that many defects attend an exclusively chemical and too narrow view of rock analysis. In this respect, it is pleasing to be able to call in Cordier's work as an illustration of a liberal mode of enquiry, for the

[1] "The Quantitative Classification of Igneous Rocks": Science Progress, No. 2, 1906.

modern petrographer stands to gain by a sympathetic consideration of the methods which he used. By way of example, we may again refer to Dr. Washington's work on "The Roman Comagmatic Region." He there states that zircon has not hitherto been recorded authentically as occurring in the rocks of this region. We are inclined to ask what efforts have been put forth to find it. Have the surface deposits, such as river sands, been carefully examined?

Experience indicates that an examination of the sands lying in the streams which flow over the Italian basalts would almost inevitably reveal the presence of zircon and other minerals of petrographical importance. In making this statement we merely echo a note emitted by Bellevue 107 years ago. It should be unnecessary to point out that the mere examination of a few rock slices, or the analysis of one gram of a crushed rock, is not a fair way of determining the presence or absence of zircon in the rocks of a region involving hundreds of cubic miles. Perhaps a few figures will make this point more striking.

We may safely assert that an amount of zircon equivalent to 0·01 per cent.[1] of a basalt would probably be overlooked in a chemical analysis of the crushed rock, and appears usually to be missed in rock sections. And yet a cubic metre of such a rock would carry about 300 grams of zircon, assuming the latter to be uniformly distributed, which it usually is. In other words, a cubic yard of such a rock would carry about ½ lb. of zircon, from which we infer that a cubic mile would carry well over a million tons of this mineral. Hence we see that hundreds of millions of tons of zircon may be disseminated through the igneous rocks of a petrographic province, although it would not be detected by the chemical methods now in vogue.[2] It thus seems reasonable to urge that, if we are to talk of comagmatic regions, we cannot remain satisfied with the results of analysis applied to such small quantities of crushed rock as will barely cover the bottom of a crucible.

Bellevue and Cordier exhibit for us a way out of these difficulties. The stream deposits of a region retain the heavy residues which have resulted from disintegration carried out through immense periods of time and on numberless tons of material. The petrographer has foolishly left the study of these deposits to the prospector. From such deposits a miner's panning operation clears out most of the quartz; a magnetic separation eliminates the ferromagnetic minerals, and when this is done it is very seldom indeed, if ever, that zircon is not left behind in considerable quantity, and is readily identified with the microscope. If the rocks themselves are to be examined, they may be crushed, and in imitation of Chrustschoff, a few hundred grams of the crushings may be manipulated by physical methods to secure a zircon residue.

Zircon is not alone in this respect as a mineral the importance of whose regional dissemination is liable to be overlooked, though it is perhaps the commonest instance. The extensive distribution of

[1] Allowing for the inclusions of such zircons, this would correspond to not more than 0·005 per cent. of ZrO_2.

[2] For the estimation of zirconia, Dr. Washington recommends the use of one gram of the crushed rock. See "Manual of the Chemical Analysis of Rocks," 1904.

monazite in small crystals in granites and gneisses is also of some importance, especially now that the radio-activity of rocks is being so much discussed. Considerations such as these may have an important bearing on the study of petrographic provinces. The possibility of using such minerals as supplementary magmatic indicators has not yet been considered; but if ever the eruptive rocks of the earth's crust are mapped out in a series of provinces, it is possible that such indicators may be important. These views give strength to the old-fashioned belief that natural mineral assemblages are more important than artificial norms. It may be, indeed, that future work will confirm the American method of making chemical analyses and artificial norms the primary basis of classification; but it is more likely that the working out of natural mineral assemblages on a comprehensive scale, and the characterisation of peculiarities in the minerals themselves, will be the ultimate goal of systematic petrography.

V.—The Fauna of the Bokkeveld Beds.

By F. R. Cowper Reed, M.A., F.G.S.

IT is useful from time to time to take stock of our knowledge in connection with such a geological problem as that of the fauna of the Bokkeveld Beds, so that we may ascertain to what stage in the process of its elucidation we have arrived, and may note the direction in which the evidence is pointing. An indication of the principal gaps in our knowledge may also be obtained in this manner, and new suggestions as to the more promising lines of investigation. The conclusions arrived at from such a survey may be employed tentatively as working hypotheses, but it may be premature to base upon them confident generalisations. Approaching the question of the composition, relations, origin, and distribution of the Bokkeveld fauna in this spirit of caution and with the foregoing objects in view, we find firstly that a considerable advance has been made in our knowledge of it and allied faunas during the last few years. The researches of Ulrich, Kayser, Clarke, Katzer, Thomas, and others in South America have given us an immense amount of fresh information on the Devonian faunas of that continent, and the South African fossils themselves have been studied by Lake, Schwarz, and the author. Their general poor state of preservation is a matter of regret, but the increase in the material available has cleared away some of the difficulties met with by Salter and other previous workers. Much undoubtedly remains to be learnt from work in the field, and we may expect further yields of new species from different localities in the immense area still to be explored.

The references given at the end of this paper do not aim at being a complete list of all recent literature dealing with the subject of the Devonian faunas of South Africa and South America, for only those works are quoted which appear to the writer to be of special interest or importance in connection with the Bokkeveld fossils.

Stratigraphy.

The stratigraphical relations and sequence of the beds comprised in the Bokkeveld Series have been carefully observed in many parts of the Cape, and the succession of the beds, where typically developed, has been recently given by Rogers (1), and may be concisely expressed as follows (in descending order):—

Shales	500 ft.	
Fourth Sandstone	100 ft.	These beds are not so well defined as the lower divisions, and they contain only badly preserved plant-remains.
Shales	300 ft.	
Third Sandstone	100 ft.	
Shales	about 350 ft.	Often micaceous, with thin interbedded quartzites and usually few fossils (*Lingula*, *Nuculites*, crinoid stems, a trilobite, *Cauularia*, plant-remains).
Second Sandstone	400 ft.	Many shale beds. Few fossils; *Spirifer* occasionally abundant.
Shales	100–300 ft.	Fossiliferous (especially starfish, but also many species occurring in lower shales).
First Sandstone	150 ft.	Slightly calcareous, containing many fossils locally, especially *Spirifer* and *Leptocælia*.
Shales and thin Sandstones	about 300 ft.	Often containing nodules, and many fossils (*Phacops*, *Homalonotus*, *Leptocælia*, *Spirifer*, *Chonetes*, *Orthothetes*, *Orthoceras*, *Bellerophon*, *Nuculites*, and Crinoids).

A definite sequence of fossil forms in the successive beds might reasonably be expected, but Schwarz (2, p. 347) has recently declared that in spite of long and determined efforts he has failed to recognise any zonal succession or assortment of species in the series. This is distinctly disappointing, as in the homotaxial Devonian of South America certain, though not very strongly marked, faunistic differences are noticeable. A more or less decided difference in the faunistic facies can, however, be observed in the Bokkeveld Series, which is connected with the lithological character of the rocks; thus the shales possess a different assemblage of fossils to the sandstones, but this difference is seemingly due to bionomical causes and to the nature of the environment as expressed in the sedimentation rather than to a chronological replacement of types and a succession of different faunas each of stratigraphical significance. Accordingly we find ourselves forced at the present time to regard the fauna of the entire Bokkeveld Series as composing a simple and stratigraphically indivisible whole, even the faunules being scarcely distinguished as yet, though future work may modify this conclusion.

It has, indeed, been observed that there are peculiarities in the horizontal distribution of some of the organisms; for instance, the genus *Homalonotus* predominates in the western and northern, the *Spirifers* in the central, and the ornate *Phacops* in the eastern outcrops, according to Schwarz (2). But to what these facts point is at present uncertain.

From the foregoing remarks it will be seen that in the present state of our knowledge we must include all the fossils from every locality and bed in the same list, and this principle is accordingly followed.

Composition of the Fauna.

The various zoological groups of organisms are treated here separately in order to discuss conveniently the special characters of various members and of the general features of each group.

(*a*) *Trilobita.*

The trilobites include the following species, adopting Schwarz's (2, pp. 382–400) modifications of Lake's (3) list:—

Homalonotus ingrestis, Schwarz.
H. colossus, Lake.
H. Herscheli, Murchison.
H. hippocampus, Schwarz.
H. horridus, Schwarz.
H. ker, Schwarz.
H. peravmatus, Frech.
H. quernus, Lake.
H. Herscheli, var. or sp. nov., Schwarz.
H. sp., Lake.
Phacops acacia, Schwarz.
Ph. (Acaste?) africanus, Salter.
Ph. arbutus, Lake.
Ph. (Cryphæus) caffer, Salter.
Ph. (Cr.) callitelus, Schwarz.
Ph. (Cr.) Ceres, Schwarz.
Ph. cristagalli (Woodward).
Ph. (Cr.) Gydouei, Schwarz.
Ph. impressus, Lake.
Ph. ocellus, Lake.
Ph. pygilus, Lake.
Phacops ? sp., Lake.
Dalmanites lunatus, Lake.
D. sp., Lake.
Proetus maclaeus, Lake (? = *Pr. Ricardi*, Schenck).
Typhloniscus Baini, Salter.

By the foregoing list it will be observed that out of the 26 species of trilobites so far recorded, 22 (or 24 if we include *Dalmanites* in the genus *Phacops*) belong either to the genus *Homalonotus* or *Phacops*, using the latter name in a broad sense. The distinction of the various species and their precise number is a matter of some uncertainty, some of them having been founded on isolated pygidia and others on isolated head-shields, which in some cases at any rate probably belong to the same species. There is also a difference of opinion as to the specific union of some of the types, Schwarz splitting up Salter and Lake's *H. Herscheli* into four species, and ascribing Lake's type of *Ph. cristagalli* to a new species, *Ph. acacia*.

In the above list the subgeneric names and references of certain of the Phacopidæ are given according to Schwarz and Lake's usage. But it may be pointed out that neither of the terms *Acaste* nor *Cryphæus* can be applied to trilobites for reasons of priority (4) (5). With regard to the rightful inclusion of any of the South African species in either of the two groups or subgenera signified by these names, Salter, Lake, and Schwarz have generally been doubtful, though Lake (3, p. 211) says that *Ph. caffer* is a "true *Cryphæus*."

The group designated by the name *Cryphæus* (Green, 1837) was founded on the American species *Cr. Boothi*, Green, in which the axis of the pygidium has 10–14 rings and the lateral lobes 5 ribs produced into spines round the margin, and there is also a more or less developed median terminal spine in the variety *Cr. callitelus*, Green. Hall & Clarke (6, p. xxxiii) defined the subgenus *Cryphæus* (genus *Dalmanites*) as follows: "Genal angles produced into long, often laterally compressed, and narrow spines. Posterior thoracic segments produced and acute. Pygidium with five annulations and five pairs of marginal lobes or spines. Terminal lobe more or less developed." *Ph. caffer* has 10–11 rings on the axis of the pygidium and 5 ribs on each lateral lobe produced into spines. *Ph. ocellus* and *Ph. impressus* are probably also allied, though the pygidial axis in the former bears only 7 rings and in the latter only 8–9. In *Cr. Barrisi*, Hall, of the Hamilton Group there are only 6–8 rings on the axis, so that the small number in these two species is not quite exceptional.

Ph. callitris is said by Schwarz (2, p. 394) to agree in many particulars with *Ph. ocellus*. *Ph. Gydowi* is similar in many respects, and *Ph. Ceres* is undoubtedly allied. In all these species there is a marked tendency for the second pair of glabellar lateral furrows to be reduced and not to enter the axial furrows, resulting in a more or less complete fusion of the first and second lateral lobes of the glabella. The same feature is met with in *Acaste* (= *Phacopidella*), which is a Silurian group, comprising *Ph. Downingiæ*.

The genal angles are not produced into long spines, but where the head-shield is sufficiently known they seemed to have been angular (*Ph. impressus*), rounded (*Ph. ocellus*), or furnished with small laterally directed spines (*Ph. callitris*). Herein they differ markedly from typical *Cryphæus*, and seem to furnish an additional point of resemblance to *Acaste*. If a distinctive name for this group is required, the name *Metacryphæus* is suggested.

The remaining Phacopidæ from the Bokkeveld Beds seem to fall into another group which in many respects resembles that containing *Dalmanites anchiops*, Green, and was mistakenly referred by Hall and Clarke to McCoy's subgenus *Chasmops*, which has completely different characters (4, p. 10). The definition of the subgenus according to Hall & Clarke (6, p. xxxiii) was apparently drawn up from the type of *D. anchiops* of the Oriskany Sandstone and Upper Helderberg, and runs as follows: "Genal angles usually produced into spines. Frontal lobe of the glabella large, transverse, and not intersected by the facial sutures. Lateral lobes unequal, the first and second pairs being coalesced and the third pair nearly obsolete. Pygidium large, sometimes with a terminal spine." *D. anchiops*, Green (6, p. 59, pl. ix, figs. 1–6, 10, 12, 13; pl. x, figs. 1–14), has genal angles produced into stout long spines; there is a nuchal spine on the occipital ring; the first and second lateral lobes of the glabella have coalesced owing to the reduction of the second lateral furrows; the eyes are large and lunate and appressed to the first and second coalesced lobes; the pygidium has an axis with 9–14 rings and lateral lobes with 8–9 ribs, and it is produced into a more or less upturned tapering mucronate termination. In the South African *Ph. cristagalli*, *Ph. arbuteus*, and *Ph. acacia* we see several of these features. The first has precisely the same type of pygidium, but it has only seven lateral ribs, and these are tuberculated, and the axis, which consists of *eight* rings, carries a single row of median spines like the thorax. The head-shield is unknown. In *Ph. arbuteus* there is a slight reduction of the second lateral furrows, the neck-segment bears a strong median spine, and the pygidium has the typical mucronate shape, but only bears 8 rings on the axis and 5 ribs on the lateral lobes. The axis of the thorax bears a median spine on each segment, but they seem to be absent from the pygidium. In *Ph. acacia* the neck-segment bears a strong median spine, the genal angles are furnished with short spines, the third glabellar lateral furrows (as in *Ph. arbuteus*) are specially deep, the axis of the thoracic segments bears median spines as in the other two species. *Ph. pupillus*, only known by an incomplete head, has cranidial characters of precisely the same type.

With regard to *Ph. africanus*, which has been suggested to belong

to *Acaste* (= *Phacopidella*, Reed), the head has exactly the same general characters as the foregoing species, i.e., a strong nuchal spine, a very deep third glabellar furrow, a median spine (probably, according to Lake) on each thoracic axial ring, and a pygidial axis produced beyond the margin bearing 9 rings, with 5 ribs on each lateral lobe. Schwarz (2, pp. 398–399) has indeed hinted that it may belong to the *cristagalli* group, and Salter believed that the genal angles were spined, thus increasing the resemblance. There does not therefore appear to be sufficient grounds for separating it from this group, and I would refer this whole set of species to a special subgroup of *D. anchiops* characterised (1) by fewer (typically 8) segments in the pygidium, only 5 pairs of ribs being present as a rule on the lateral lobes; (2) by the presence of median spines on the axis of thorax and pygidium; (3) by small, instead of stout and long, genal spines (in *D. anchiops*, var. *armatus*, Hall (6, p. 62, pl. ix, figs. 7–9), the genal spines are inconspicuous or obsolete); (4) by less pronounced coalescence of first and second lateral lobes of glabella. (Nom. prop. *Anchiopella*.) Clarke (8, p. 33) considered the Maecurú species described by him as *Dalmanites galea* as a representative of the genus *Acaste*, Salter, on the strength of the coalescence of the first and second lateral lobes of the glabella, rounded genal angles, and general characters of the head-shield on which the species was founded. In discussing its resemblance (8, p. 57) to *D. gonzagaanus*, Clarke, from the same horizon in Parana, he alludes to its resemblance to *D. anchiops*, var. *sobrinus*, Hall, of the Schoharie grit.

The relations of several of the trilobites to South American forms have been pointed out by Lake and Schwarz, and in the light of recent knowledge the identical or allied species are as follows:—

(B. = Bolivia; Br. = Brazil; A. = Argentina.)

Phacops arbuteus	*Phacops* cf. *arbuteus*. B.
Ph. (*Cryphæus*) *caffer* ...	*Cr. giganteus*, Ulr. B. *Cr. paitúna*, Clarke. Br., B. *Cr. concexus*, Ulr. B.
Ph. africanus	*Ph.* (*Acaste*) *devonicus*, Ulr. B. *Dalmanites galea*, Clarke. Br. *D. gonzagaanus*, Clarke. Br.
Ph. Ceres	*Cr. giganteus*, Ulr. B.
Dalmanites sp.	*D. Clarkei*, Ulr. B. *D. maecurúa*, Clarke. Br., B.
Homalonotus Herscheli ...	*H. Derbyi*, Clarke. Br.

The relations of the two South African groups of Phacopidæ to the North American *D. Boothi* and *D. anchiops* have been above discussed. Clarke (8, pp. 80, 98) has remarked that the cephalon of *D. galea* and *Ph. devonicus*, Ulrich (9, p. 21, t. i, figs. 14*a*, *b*, 15), have a Silurian type of Phacopid structure, and Lake also alludes to it, but except in the reduction of the second pair of glabellar furrows the resemblance is rather remote.

The affinities of the species of *Homalonotus* from South Africa with those of South or North America are not very marked, and Lake compares some of them to European species of Coblenzian age. According to Schwarz, all the Bokkeveld *Homalonoti* have a strong family likeness, and they do not seem allied closely to any of the

five species from South America mentioned by Thomas (10), except to *H. Derbyi*, Clarke. The latter species, according to Katzer (15, p. 21), has its allies in the Silurian of North America. Haug (11) has recorded *H. Herschelı* from the central Sahara, but Schwarz (2, p. 387) says this fossil comes nearest to the South African *H. agrestis*, and that it reminds him more of *H. obtusus*, Sandberger, from the Upper Lower Devonian of the Rhine. A species of *Crypheus* has also been recognised by Haug from the same locality.

No true member of *Phacops*, sens. str., is known to be present in the Bokkeveld Beds, but in South America a fossil from Bolivia was long ago attributed to *Ph. latifrons* by Forbes (29), while Ulrich (9) has described from the same region a peculiar type, *Ph. Dagincourti*, with submarginal denticulations to the head-shield. A form compared with *Ph. rana*, Green, has also been figured by Kayser from Argentina (20, p. 284). The South African *Typhlomiscus Baini* is unique, and its true relations are still somewhat problematical. *Proetus malacus* is not very satisfactorily known.

(*b*) *Brachiopoda.*

The Brachiopoda are represented by the following large number of species:—

Lingula aff. *densa*, Hall.
L. sp., Reed.
Orbiculoidea Baini (Morr. & Sh.).
Strophicalonta cf. *cincinna* (Morr. & Sh.).
Strophonella sp., Reed.
Orthothetes Salteanus (Morr. & Sh.).
Chonetes falklandicus, Morr. & Sh.
Ch. cf. *coronatus*, Conr.
Ch. cf. *Arcei*, Ulrich.
Ch. aff. *setiger*, Hall.
Orthis sp. (?), Reed.
Rhynchonella (*Camarotachia*?) sp., Reed.
Rensselæria reflecta, Schwarz (? = *R.* sp. α, Reed).
R. cf. *conglacutana*, Fuchs.
R. hottentota, Schwarz (? *Rhynchospira*).
R. sp. β, Reed.
R.? sp., Reed.
Trigeria aff. *Gaudeti*, Oehl.
Tr. ? *Rhynchospira*) *scaplex*, Schwarz.
Rhynchospira ? cf. *Silveti*, Ulrich.
Cryptonella Baini, Sharpe.
Cr. ? sp., Reed (? = *Oriskania navicella*, Hall & Cl.).
Spirifer antarcticus, Morr. & Sh. (= *Sp. Orbignyi*, Reed = *Sp. antarcticus* + *Sp. Orbignyi*, Schwarz).
Sp. Ceres, Reed.
Sp. cf. *pedroanus*, Hartt (included in *Sp. antarcticus* by Schwarz).
Sp. sp. α, Reed (included in *Sp. antarcticus* by Schwarz).
Sp. sp. β, Reed.
Ambocœlia umbonata (Conr.).
Retzia cf. *Adriei*, De Vern.
Leptocœlia flabellites, Conr.
Scaphiocœlia ? *africana*, Reed.
Ptychospira variegata, Reed.
Vitulina pustulosa, Hall.
? *Tropidoleptus carinatus* (Conr.).

Some difference of opinion with regard to the generic position and specific relations of the fossils referred to the genera *Trigeria*, *Rhynchospira*, and *Rensselæria* exists (2) (5), but until better preserved specimens are available it does not seem possible to settle the vexed questions. In the case of the Spiriferidæ the separation of some of the species is a matter of opinion, but Mr. J. Thomas (10, p. 261) and Mr. E. T. Newton (12, p. 252) have recently supported my contention as to the undesirability of separating *Sp. antarcticus* and *Sp. Orbignyi*, and my attention has also been called to a previous paper by Scupin (13) on these very species. Both *Sp. antarcticus* and *Sp. Orbignyi* of the Falkland Islands are held by him to represent only one variety of Hall's species *Sp. arrectus*, and for this variety

the name *antarcticus* is retained. To this variety belongs also the Bolivian species *Sp. Chuquisaca*, Ulrich. Some of the South African specimens figured by Sharpe (14, pl. xxvi, figs. 1, 3, excl. cet.) under the names *Sp. antarcticus* and *Sp. Orbigni* are referred to the typical form of *Sp. arrectus*. The species *Sp. Hanckinsi* (Morr. & Sh.) from the Falkland Islands is chosen to designate another variety of *Sp. arrectus*, to which also *Sp. Vogeli*, V. Ammon, from Brazil, is assigned. According to Scupin, therefore, the South African, Brazilian, Bolivian, Falkland Islands, and, we may add, Argentine forms known under the diverse names of *Sp. antarcticus*, *Orbigniyi*, *Chuquisaca*, and *Vogeli* may all be included in the one North American species *Sp. arrectus*, which is closely allied to the European *Sp. primævus*.

In the Devonian beds of Tassili in the Sahara, Haug (11) records *Spirifer* cf. *Rousseaui*, M. Rouault, which, as he states, belongs to the same group.

The occurrence of *Tropidoleptus carinatus* in the Bokkeveld Beds, though mentioned by Ulrich (9), is somewhat doubtful, no other palæontologist having observed it.

(*To be continued in our next number.*)

VI.—The Chemical Composition of Igneous Rocks: A New Method of obtaining it.

By Arthur Wade, F.G.S.

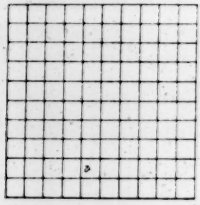
ANY science which cannot express its conclusions by means of number must still be regarded as in its infancy. Such an expression is the only test of precision and accuracy of thought on the part of its workers, and such important characters only develop, as in the human mind, when the romance and rashness of youth have given place to the more cautious and matter-of-fact features of maturity. It is therefore a sign of healthy development when those engaged in the study of petrology begin to turn their attention towards careful numerical calculation as a basis of classification.

This has been done in a very elaborate fashion by the authors of the new "Quantitative Classification of the Igneous Rocks,"[1] and whilst reserving our opinion with regard to the ultimate value of this new American scheme, there is no doubt that it emphasises the importance of certain features which we in Britain are apt to hold too lightly. The most important of these is the absolutely essential nature of obtaining some fairly accurate idea of the chemical composition of a rock before proceeding to assign to it a position in any rock-group or family. The making of a complete chemical analysis of a rock is a somewhat tedious and delicate process requiring much technical

[1] Cross, Iddings, Pirsson, & Washington: "Quantitative Classification of the Igneous Rocks"; Chicago, 1903.

skill, and few petrologists find themselves able to undertake such work, though the need for it is becoming more and more apparent. A valuable alternative, however, remains. Many remarkably accurate and useful results have been obtained by the application of the 'Linear Traversing Method'[1] of Rosiwal. By this method the percentage mineral composition of the rock is obtained. By multiplying each quantity by its density and making use of the known chemical composition of the minerals we get a fairly accurate statement of the quantitative chemical composition of the rock.

I wish, however, to suggest a method which will be found, I hope, more simple, and with a little care equally effective. Instead of the ordinary eyepiece with single cross wires one should be obtained fitted so as to give a square field. This field should be crossed by wires dividing each side of the square into ten equal parts, and the whole area therefore into 100 equal divisions. In making an examination of any rock section the percentage mineral composition of the part of the slide under examination is easily found by simply counting the squares occupied by the several mineral species present. By taking a number of observations in different parts of the same slide and obtaining an average a fairly close approximation to the actual chemical composition of the rock from which the section is cut can be obtained by a skilful observer. This average would, of course, become more closely approximate by considering more than one section cut from the same specimen.



Field of Eyepiece showing the arrangement of crosswires.

Thus by means of this simple arrangement a student should be expected, not merely to identify the mineral constituents present in a rock section, and so obtain a general idea of its relationships, but to express his conclusions with regard to both mineral constitution and chemical composition by means of number. This would constitute a real step in advance in the study of petrology as carried on at present in this country, and would probably lay the foundations for a more satisfactory system of classifying the igneous rocks than the somewhat hazy one now in vogue.

[1] See Rosiwal, Verhuch. Wien Geol. Reichs. Anst., vol. xxxii (1898), or "Quant. Classif." above, p. 204.

NOTICES OF MEMOIRS.

Arrhenius' Theory of the Physical Causes of Vulcanicity.[1] By R. H. Rastall, M.A., F.G.S., Fellow of Christ's College, Cambridge.

[*Note.*—As this paper in its original form is very inaccessible to most readers, its importance has perhaps scarcely been appreciated in this country; the following short abstract has been made at the suggestion of Professor Bonney, in the hope that it may be of use to students of geology and others.]

(1) *The Condition of the Earth's Interior.*

THE conclusions of astronomers and physicists are irreconcilable with the hypothesis of the existence of any considerable amount of matter in the liquid form in the interior of the earth. This idea rests for the most part on a misconception of the physical properties of matter under the enormously high pressures which prevail at great depths. Nearly all known substances, with the notable exception of water, contract in volume on solidifying, and in consequence their melting-point is raised by pressure. The investigations, however, of Damien, Barus, and especially of Tammann, have shown that at very high pressures this relation no longer holds. Tammann found that the maximum melting-point of dimethylethyl-carbinol is reached under a pressure of 4,750 atmospheres, and at higher pressures the melting-point falls; it seems probable that other substances would behave in a similar manner under similar conditions. Hence it appears that at great depths the constituents of the globe must be in reality in the gaseous state, since pressure cannot keep them solid or even liquid by raising the melting-point. But the physical properties of gases under such conditions must be very unlike those with which we are acquainted. The true difference between a liquid, a solid, and a gas lies in the rate at which they respectively undergo deformation under stress. The necessary physical constants have been determined by Reinganum in the case of isopentane at the highest attainable pressures, and from these it is calculated by extrapolation that at a depth of 1,000 kilometres the compressibility of gaseous isopentane must be about equal to that of steel. The temperature in this case must be far above the critical point, and the material is actually gaseous, though its physical properties resemble those which are commonly associated with the idea of a solid. Rock-magma under similar conditions would undoubtedly possess a still lower compressibility.

Assuming the temperature-gradient to be 3° C. per 100 metres, the melting-point of most rocks, about 1,200° C. is attained at a depth of about 40 kilometres, while below this lies a liquid zone. At a still greater depth the critical point is passed, and the magma is in the gaseous state, though intensely rigid. From the high density of the earth as a whole, compared with that of the visible portion, it appears that the inner nucleus consists of some metallic substance,

[1] Arrhenius, "Zur Physik des Vulcanismus": Geologiska Foreningens i Stockholm Forhandlingar, Band xxii (1900), p. 395.

probably iron. From the known data it is easy to calculate that about 80 per cent. of the earth's diameter must be occupied by gaseous iron, 15 per cent. by gaseous rock-magma, and 4 per cent. by liquid magma; the rest, less than 1 per cent., forms the solid crust.

These theoretical conclusions are supported by the results of earthquake observations. The seismograph record of a distant earthquake shock shows a clear division into two phases, viz. preliminary tremors and the principal shock. The explanation of this fact is, as Milne pointed out, that the principal shock is propagated along the crust, while the preliminary tremors travel along the chord of the arc. Since these latter are much diminished in intensity, it follows that the internal friction of the material of the inner parts of the globe must be very great, which is in harmony with the assumption of a liquid or gaseous condition rather than with the solid state.

(2) *Volcanic Phenomena.*

It is unnecessary to prove in detail that in all volcanic eruptions great quantities of gases, and in particular water-vapour, are given off, and the pressure of this gaseous water at a temperature above its critical point is undoubtedly the chief motive-power of the eruption. Each explosion relieves the pressure for the time being, but the frequent recurrence of eruptions from the same vent shows that further supplies of water must by some means reach the magma, and this in spite of enormous counter-pressure. The ocean-floor, with its capillaries, may be supposed to act as a semi-permeable membrane, through which the water penetrates by osmotic pressure. Assuming the density of the magma to be about 2·7, it can easily be calculated that in order to overcome the pressure of the overlying column of rock the osmotic pressure at a depth of 10,000 metres must be about 1,700 atmospheres, and this in itself is not inconceivable. But since the dissolved constituents of the magma show this high osmotic pressure they must enter into chemical combination with the water.

According to Thomsen's measurements water at the ordinary temperature is a very weak acid, about 100 times weaker than silicic acid, but on raising the temperature these relations no longer hold. While silicic acid, which has a heat of neutralization equal to those of nitric and hydrochloric acids, does not change its strength notably, the case is very different with water. From the data with regard to the behaviour of water between 0° and 50°, it can be calculated by a well-known extrapolation formula that at 300° water and silicic acid are equally strong, at 1,000° water is 80 times, and at 2,000° 300 times as strong as silicic acid. It is true that this result is obtained purely by extrapolation, but it is of no practical importance whether water is 300 times or only 100 times as strong as silicic acid, so long as it is distinctly the stronger, and this the calculation shows with certainty.

(3) *The Chemical and Physical Action of Water on the Magma.*

Let us now suppose water to be in contact through a semi-permeable membrane (the sea-floor), with a magma between 1,000° and 2,000° C. Water penetrates into the magma by osmosis and acts as a relatively powerful acid on the silicates, by which means silicic

acid and bases are set free. These combine with more magma, and form acid and basic silicates. Further addition of water then sets up new decompositions, but some water always remains free in the magma, although on account of its relatively small amount it has a very low vapour-pressure, in accordance with Raoult's law. The process can go on till a great part of the magma is decomposed. The magma must also increase in volume on taking up water, by very nearly the volume of the water absorbed.

The swollen magma, which has also become more fluid, exerts pressure on all sides, and the column rises still further in the vent which is in connection with the magma-basin. On rising, the magma is cooled in the narrow vent, the water continuously becomes a weaker acid, and is displaced by silicic acid from the hydrates; the pressure of the aqueous vapour rises in spite of the fall of temperature, and if the watery layer comes near enough to the surface, and therefore under sufficiently low external pressure, steam explosions will occur.

According to this theory a volcano acts very like a geyser. As the water rises in a geyser, so it does in a volcano, though in this case it is mostly in chemical combination with the magma. At great depths, and therefore under high pressures, the water in the geyser and the watery magma in the volcanic vent are under higher pressures than those corresponding to the maximum tension of the water-vapour, and no explosion is possible. When a magma enters the vent of the volcano and rises in it, it at last reaches a point where, on account of separation of water from the magma through cooling, the pressure of the water-vapour exceeds the external pressure. Then an explosion occurs, blowing a passage through the overlying layers, and thus leading to renewed explosions by relief of pressure. This goes on till so much water has separated from the magma that the remainder cannot overcome the external pressure. Then ensues a period of temporary quiescence, with slow loss of water-vapour by diffusion, until after a sufficient lapse of time so much water penetrates into the magma-basin that the process begins anew.

REVIEWS.

I.—New Geological Survey Maps and Memoirs.

1. The Geology of Falmouth and Truro and of the Mining District of Camborne and Redruth. By J. B. Hill, R.N., and D. A. MacAlister, A.R.S.M., F.G.S.; with Petrological Notes by J. S. Flett, M.B., D.Sc. 8vo, cloth; pp. x and 336, 24 plates. Pages 1–112 form Part I, Geology; pp. 113–314 form Part II, Mining; pp. 315–324 are Bibliography; and pp. 325–335, Index. Price 7*s.* 6*d.*; in explanation of colour-printed map, Sheet 352, 1*s.* 6*d.* (E. Stanford: London, 1906.)

2. The Geology of the Country near Newquay. By Clement Reid, F.R.S., F.L.S., F.G.S., and J. B. Scrivenor, M.A., F.G.S.; with contributions by J. S. Flett, M.A., D.Sc., W. Pollard, M.A.,

D.Sc., and D. A. MacAlister, A.R.S.M. 1906. price 3*s.*; 9½ inches by 6 inches; pp. iv + 131, with 6 plates (photographic process) and 23 figures. Pages 1–90 are devoted to Geology; pp. 91–119 form Appendix I, Mines; pp. 120–122 form Appendix II, Bibliography; pp. 123–131, Index. In explanation of Sheet 346.

AMONG the recent publications of the Geological Survey are Sheets 346 (Newquay) and 352 (Falmouth) of the New Series of one inch to one mile ($\frac{1}{63360}$) colour-printed maps of England and Wales, both dated 1906, price 1*s.* 6*d.* each. The area comprised in Sheet 352 extends from Gerrans Bay on the east to (and inclusive of) Camborne on the west, from Porthtowan on the north to Falmouth Bay on the south. The formations represented are in ascending order. I. The Mylor Series; in the south-west of the map it occupies almost two-thirds of the area represented, if we disregard the great granite masses intrusive in it. The Mylor Series encloses the various greenstones, the greater portion of the elvan dykes, and, in conjunction with the granites, almost the whole of the mineral lodes. II. The Falmouth Series occurs in several minor and three considerable areas—(1) between Porthtowan and Reskajeage Downs; (2) between St. Day and Truro; (3) on the coast of Falmouth Bay. III. The Porthscatho Series occupies a large area in the east and extends in a mile-wide band along the north of the area. IV. The Veryan Series is restricted on the map to a triangular tract of about half a square mile on Gerrans Bay.

In the legend of the map the preceding formations are merely bracketed together as Lower Palæozoic, but in the corresponding memoir they, together with the Lower Devonian Grampound Beds, which form a mile-wide strip along the northern margin of the map area, are grouped together as Killas, viz. slate deposits.

A deposit of quartz gravel, occupying an area less than half a mile in length and about a quarter of a mile in breadth, occurs near Polcrebo, in the heart of the granite district, and is mapped as Pliocene. "Raised Beaches, Head, Alluvium, and Blown Sand" complete the list of sedimentary formations. Perhaps the most interesting feature of the map is the rudely circular Carnmenellis boss of muscovite-biotite granite, about 9 miles in diameter, which occupies the south-west of the map. Like the two smaller adjacent granite masses of Carn Brea and Carn Marth, it is surrounded by an aureole of metamorphism. Intrusions of greenstone (largely referable to the group of epidiorites), elvan, or quartz-porphyry dykes, the latter generally trending about east-north-east (like the mineral lodes), and mica traps or minettes are also shown. The numerous mineral lodes of the area are almost entirely confined to the western district, and are mainly restricted to the neighbourhood of the granite, but continue to occur for a distance of 4 miles eastward of the granite.

A section below the map shows the structure of the country along a line from west-north-west to east-south-east, from Reskajeage Downs through Dolcoath Mine, Carn Brea, and Carnmenellis granite to Falmouth and Pendennis Point.

Sheet 346 (Newquay) shows the country immediately to north of that represented in Sheet 352, and includes Watergate Bay, Newquay,

Perranporth and St. Agnes. About half the area represented is sea. In ascending order the formations shown are: (1) Dartmouth Beds (Lower Old Red Sandstone), purple and green fine-grained sandy micaceous shales or slates, with occasional bands of grit, and containing fish-remains (*Pteraspis cornubicus*, etc.). They occur in a faulted and much broken anticline which has its crest in Watergate Bay and measures 4½ miles from east to west by 2 miles from north to south. (2) Lower Devonian Meadfoot Beds, which occupy about one-half of the land area shown, chiefly to south, but also in a narrow band to north of the Dartmouth Beds. The Meadfoot Beds consist of shales, slates, and thin limestones, and seem to rest quite conformably on and to pass gradually down into the Dartmouth Beds. (3) Lower Devonian Staddon Grits on the north, Ladock Beds (basal Devonian) on the south. These consist of silts, sandy slates, sandstones, and coarse grits. The Staddon Grits (so far as shown) occupy an area 3½ miles from east to west by 1¼ from north to south in the north-east corner of the map. They strike east-south-east, and this strike if prolonged would make them meet and be continuous with the similar grits of Ladock on the south side of the anticlinal axis (of Dartmouth Beds and Meadfoot Beds). The continuity, however, is broken by the intrusion of the St. Austell granite (not in map), so the southern area is treated separately. The Ladock Beds are continuous with the Grampound Beds of Sheet 352, and occupy an area 13½ miles from east to west by 4½ miles from north to south at the south of the map 346. Pliocene beds termed St. Agnes Sands and consisting of unfossiliferous sands and clays, forming an old shore-deposit, almost surround St. Agnes Beacon near the south-west coastline. They cover a crescentic area 1½ miles long along the curve by ¼ mile broad. Raised Beach deposits, Valley Gravel and Head, Alluvium and Submerged Forest, and Blown Sand are the remaining deposits shown. Granite occurs west of St. Agnes Beacon and at Cligga Head, and is surrounded in each case by an aureole of metamorphism. Elvans or quartz porphyries, lamprophyres or mica traps, and greenstones are shown.

A section below the map shows the structure of the country between Denzell Downs on the north-east cutting across the anticline of Devonian rocks, by Perranporth to St. Agnes Beacon on the south-west.

B. Hobson.

II.—Memoirs of the Geological Survey, England and Wales. Explanation of Sheet 311: The Geology of the Country between Wellington and Chard. By W. A. E. Ussher, F.G.S.; with contributions by H. B. Woodward, F.R.S., and A. J. Jukes-Browne, B.A., F.G.S. 8vo; pp. vi and 68. Price 1*s.* 3*d.*; colour-printed map, 1*s.* 6*d.* E. Stanford, 12–14, Long Acre, London, 1906. (Issued February, 1907.)

THE Geological Survey have issued (price 1*s.* 6*d.*) Sheet 311 (Wellington) of the New Series of one inch to one mile ($\frac{1}{63360}$) colour-printed maps of England and Wales. The area comprised in the map includes the southern suburbs of Taunton at the northern margin, Ilminster close to the eastern border, Chard 3¼ miles from the

south-east corner, Wellington 4 miles from the north-west corner. The original one inch Geological Survey map, Sheet 21, was published probably in 1833. The area was resurveyed on the one inch Old Series map between 1870 and 1876, and the geology was transferred to the New Series map, with additions by Mr. A. J. Jukes-Browne, in 1892. The colour-printed edition is dated 1906. The principal additions to the map, which includes the famous Greensand area of the Blackdown Hills, are in the subdivisions of the New Red rocks and the insertion of the Rhætic Beds and superficial deposits. A section below the map shows the structure of the country along a line from north-west to south-east from Kittisford (near Wellington) through Church Stanton to Tatworth (near Chard).

The memoir explanatory of the map is entitled Explanation of Sheet 311: "The Geology of the Country between Wellington and Chard," by W. A. E. Ussher, F.G.S. 1906, pp. vi + 68, with 11 figures, price 1*s.* 3*d.* The strata described include a very small area of Devonian (Pilton Beds) and Lower Culm Measures, a large area of New Red Sandstone with a narrow outcrop of Rhætic, a large spread of Lias and Cretaceous, the latter largely covered by Plateau deposits (Clay with Flints, etc.). Between the five members of the New Red Series no signs of discordance have been found. The Lower Sandstone and Breccia (Permian) exhibit a passage series into the overlying Lower Marls north of the Tone Valley, comparable to that in the South Devon coast section, but which has not been detected in the intervening area. The Pebble Beds show a passage of unconsolidated pebbly sands into hard conglomerate in the vicinity of Thorn St. Margaret. A chapter is devoted to Economic Geology. In an appendix a list (of thirty items) includes the titles of the principal works on the geology of the district, and four complete pages are devoted to an index.

B. Hobson.

III.—New Geological Survey Drift-Maps, etc.

THE Geological Survey are issuing a Drift edition of the 4 miles to 1 inch Map of England and Wales. The sheets published (dated 1906) are No. 8, comprising the East Coast of England from Filey Bay to Saltfleet in Lincolnshire (most of the map represents the North Sea), and No. 12 (the sheet immediately to south of No. 8), comprising a large part of Lincolnshire, the Wash, and Norfolk (Lowestoft North station and Peterborough being included). The superficial deposits shown include, under "Drift," loam, sand and gravel, boulder-clay; and under "Recent and Post-Glacial," valley gravel, loam, alluvium, and blown sand.

As compared with the Solid Geology edition, these maps show several improvements—the railway stations are marked, many altitudes are given, more topographical detail is shown, and it is brought more nearly up to date; the colour-printing is excellent. There is only one point that the purchaser is likely to find fault with, and that is the price of the maps. The sheets only measure 15 inches by 22½ inches over the topographical work, whereas the Solid Geology

sheets measure 22 by 30 inches over the work, that is, they are twice the size. In each case the price per sheet is 2*s.* 6*d.*

Another new map issued by the Survey is Sheet 341 (West Fleet) of the New Series (colour-printed), 1 inch to 1 mile Map of England and Wales. It comprises a very small triangular bit (about 15 square miles) of Dorsetshire, including part of the Chesil Bank, and shows Oolitic rocks, from the Fuller's Earth to the Portland Sand, Pleistocene Plateau Gravel, Recent and Post-Glacial Valley Gravel, Alluvium, and Shingle, price of map 1*s.* 6*d.* (dated 1905). B. Hobson.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—February 6th, 1907.—J. E. Marr, Sc.D., F.R.S., Vice-President, in the Chair.

The following communications were read:—

1. "Note on the Cervical Vertebra of *Zeuglodon* from the Barton Clay of Barton Cliff (Hampshire)." By Charles William Andrews, B.A., D.Sc., F.R.S., F.G.S.

The author gives a brief description of a cervical vertebra from the Barton Clay of Barton Cliff. It is referred provisionally to *Zeuglodon Wanklyni*, a species described in 1876 by Professor H. G. Seeley. The skull on which this description was founded is totally lost, so that this vertebra is the only bone of a *Zeuglodon* from the Barton Clay, and, with the possible exception of a vertebra from the Brockenhurst Beds (which is the type of *Balænoptera Juddi*), the only one found in the British Isles that now exists.

2. "The Origin and Age of the Plateaus around Torquay." By Alfred John Jukes-Browne, B.A., F.G.S.

The existence of high-level plains or plateaus near Torquay has long been known, but since Pengelly's time little attention seems to have been paid to them. Pengelly believed that there were several such plains at different levels, and thought that the time of their production was not very remote. On examination, however, his evidence breaks down, and the author regards the plateaus as portions of one inclined plane.

The plateau-area has an extent of about three miles in length from north to south, and about two in width. Its highest level is found at the foot of the ridge which forms the watershed between Torbay and the estuary of the Teign. From the foot of this a platform stretches southward on each side of Barton at a level of from 350 to 340 feet; south of this is the flat summit of Lummaton Hill (also about 340 feet); and about a mile farther south are the flat-topped hills known as Yaddon and Daison Hills, both about 320 feet, and only separated by a narrow gorge cut by the little stream which flows from Barton to Torquay.

East of these hills we find a plateau area extending continuously through St. Marychurch and Babbacombe, for a distance of a mile and a half and an average width of half a mile, but cut off abruptly along

the coastline. The northern end of this plateau is about 330 feet above Ordnance datum, but it slopes gradually southward, till on Walls Hill its highest part is only 267 feet.

On the west of Torquay the old plain has been so dissected by streams, and so lowered by detritive agencies, that it is almost destroyed. Remnants, however, remain in Waldon Hill (200 feet), Stentiford Hill (230 feet), and Daddy Hole Plain (about 200 feet).

The central hills of Torquay, which are known as Warberry Hill and Lincombe Hill, rise to much greater heights (440 and 400 feet), and stand up as conspicuous eminences above the level of the surrounding plateau.

The evidence as to the age of the planation is next considered. It is proved to be post-Permian by the fact that Permian breccia forms part of the plateau-surface at St. Marychurch. It is also probably post-Cretaceous, because Cretaceous planation is not likely to have removed all the Permian. Its present dissected condition shows that it is older than the Pleistocene, and consequently an Eocene date would agree with local evidence.

The author accepts the Eocene age of the Haldon gravels and of the Bovey deposits, and adduces evidence for a connection between the Haldon plateau and the Bovey basin on the one hand, and between the Aller basin and the Torquay plateau area on the other. He regards the Bovey basin as a locally deep depression along a line of Miocene deflexion which crosses Devon from north-west to south-east, and believes the plateau-area near Torquay to be the flattened-out extension of this flexure. He thus considers the plateau to be part of the basal plain on which the Eocene deposits lie, and infers that these deposits passed directly out of the Aller basin on to this plateau, burying it to a depth of several hundred feet.

Thus it was on the surface of the Eocene deposits that the existing system of drainage was established.

The Brixham plateau, south of Torbay, presents similar features and appears to be of the same age, but in its case the drainage is northward from higher ground to the south. This plateau can be traced westward through Churston and Galmpton to Stoke Gabriel, where there is high ground both to the north and south of it. It is inferred that this plateau is the site of a second shallow flexure, the axis of which ran nearly west and east, so as to meet and merge into the other line of flexure outside the entrance of Torbay. Incidentally this would explain the formation of Torbay.

II.—February 15th, 1907.—Sir Archibald Geikie, Sc.D., D.C.L., LL.D., Sec. R.S., President, in the Chair.

Annual General Meeting.

The Reports of the Council and of the Library and Museum Committee for the year 1906 were read.

The Reports having been received, the President presented the Wollaston Medal to Prof. William Johnson Sollas, F.R.S., addressing him as follows:—

Professor Sollas.—The Council of the Geological Society has this year awarded the Wollaston Medal to you in recognition of the value of your varied and prolonged contribution to the development of Geology. There is hardly a department of our science into which you have not carried the light and impulse of your brilliant and versatile genius. You have united in no ordinary way the qualifications of an accomplished petrographer, an excellent palæontologist, an able stratigrapher, and a philosophical mineralogist, and to this wide range of accomplishment you have added an originality and inventiveness which have introduced notable improvements into the processes of research. I regard it as of special honour and pleasure that it has fallen to me to be the medium of presenting this medal to you. You have long been one of my most esteemed friends, and I trust that I may be allowed, even in this public place, to add my own personal felicitations to those of, I am sure, all the Fellows of the Society that the highest honour which we have to bestow should now be conferred upon you.

If the award is a recognition of past services in the cause of our beloved science, you will, we hope, accept it as no less an augury that we look forward with confidence to much fresh work from your hands in the future. We hope to see a flourishing School of Geology growing up at Oxford under your fostering care, and to welcome from you in the years to come many memoirs not less suggestive and important than those with which you have already enriched the literature of geology.

Professor Sollas, in reply, said:—

Mr. President,—I deeply appreciate the honour conferred upon me by the Council, and it by any means I could be reconciled to the sense of my own insignificance, awakened by the recollection of the many illustrious names that have preceded me in this place before the President's chair, it would be by your kind, I fear too kind, words, and the favour with which they have been received by the Fellows of this Society.

It is by no merit of mine that I am a lover, an ardent lover, of geology, for I feel, perhaps with a lover's partiality, that our gracious mistress, bountiful as she is fair, requires only to be seen as she truly is to captivate at once all hearts. I have found in her service a perpetual delight, and if your kind wishes should be fulfilled shall ever continue to do so, for she repays our constancy with a variety that never stales.

I know how close is the interest taken by you, Sir, in the cause of Geology at Oxford; it has been a frequent source of encouragement to me, and the hope you now express is that which lies nearest to my own heart. As a teacher I increasingly feel with advancing years how great is my debt to my masters, Huxley, Ramsay, Bonney, and, Sir, yourself, for I have been a diligent student of your teaching ever since the appearance of "The Scenery of Scotland" in 1865. But to you, Sir, and to my revered tutor, I am indebted not only for direct instruction, but for the light of example, the privilege and stimulus of friendship, and indeed for those very opportunities by which I stand here to-day. I count it, therefore, not the least of my good fortune that I receive the Wollaston Medal from your hands.

The President then presented the Murchison Medal to Mr. Alfred Harker, F.R.S., addressing him in the following words:—

Mr. Harker,—The Murchison Medal has been assigned to you as a testimony of the Council's appreciation of the importance of your contributions to Petrographical and Structural Geology. You had already distinguished yourself by your studies in cleavage, by the zeal and success with which you had thrown yourself into the pursuit of petrographical research along those modern paths in which this department of our science has been so transformed and enlarged, and lastly by the skill which you had shown in the field investigation of the ancient igneous rocks of North Wales and of part of the Lake District. With this reputation already established and yearly growing, you were induced, at my request, to enter the Geological Survey. Although the circumstances under which you joined that service formed a new departure in its usages, I have always felt that on no part of my long connection with the Survey could I look back with more satisfaction than on the arrangements which enabled us to secure your services. You speedily acquired the skill of a practised surveyor, and among the hills of Skye and Rum you had an opportunity of mapping some of the most complicated and deeply interesting pieces of volcanic

geology in this country. Having had from time to time opportunities of visiting you on the ground, I can bear witness both to the bodily vigour and endurance and to the geological enthusiasm and insight with which you climbed crags and peaks on which no geologist had set foot before you. The maps and memoirs which you have produced of these portions of the Inner Hebrides will always remain as a monument of your prowess as a field geologist and petrographer.

In handing you this Medal, which bears the honoured name of Murchison, let me wish you, on the part of the Council and of the Society at large, health, leisure, and opportunity, that you may enjoy a long, useful, and distinguished career.

Mr. Harker replied as follows:—

Mr. President, I wish, in response to what you have said, to express my very sincere acknowledgements to the Council for the distinction which they have conferred upon me. The pleasure with which I first received news of this honour has since been enhanced by the knowledge that my gratification is shared by friends and fellow-workers, and it is now crowned by the graceful words with which you have accompanied the presentation.

In my work in Skye, to which you have made kind reference, it has been my privilege to tread ground rendered classic by the labours of some of the masters of our science; and I hold it peculiarly appropriate, as it is eminently pleasing to myself, that this mark of the generous appreciation of the Council should be conveyed by one of those my predecessors—by one, moreover, who first directed my steps in a field which he had already made his own. That the work has been a labour of love I need not say to any geologist who has felt the fascination of the West Highlands—least of all, Sir, to yourself. Where the work is its own reward, so flattering a recognition as this might perhaps be deemed an unearned addition. I take leave, however, to regard it as in some part an encouragement for the future, and with it I must accept the responsibility of justifying to the best of my powers the choice of the Council.

To me, finally, this Medal will be in a special sense a memento of the ten years which I spent so pleasantly on the Geological Survey of Scotland; not only because the Medal itself was founded by a former chief of the Survey, and comes to me from the hand of one of his successors, but also because this award adds my name to a list which includes those of yourself, who, as Director-General, despatched me to the island which you knew so well; of Dr. Horne, head of the Scottish branch, my constant friend and counsellor; of Dr. Peach, my immediate superior on the Survey; and (last year) of Mr. Clough, the colleague who initiated me into the craft of geological surveying, setting a standard to which I fear his pupil has not often attained.

In handing the Lyell Medal, awarded to Dr. Joseph Frederick Whiteaves, F.R.S. Can., to Lord Strathcona, for transmission to the recipient, the President addressed him as follows:—

Lord Strathcona,—The Lyell Medal of the Geological Society is this year awarded to Dr. Joseph Frederick Whiteaves as a mark of the Council's appreciation of his prolonged and valuable contributions to the Geology and Palæontology of Canada. As a young man, before he settled in the New World, he had already shown his scientific bent by several published papers on the land and fresh-water mollusca and on the fossils of some of the Oolitic formations of Oxfordshire. Half a century ago he transferred his home and his geological energy to Canada, and from that time until now his scientific activity has known no pause. In 1876 he was appointed to succeed the illustrious Billings as Palæontologist to the Geological Survey of Canada. In that official capacity he found increased opportunity of studying the fossils that were brought to the Survey Museum from the eastern provinces, from Manitoba, and from the far shores of the Pacific Ocean. Thus every fossiliferous formation in the wide Dominion has come under his review, and he has described many new forms in various grades of the animal kingdom. Following the path so admirably opened up by his predecessor, Dr. Whiteaves has amply sustained the scientific reputation of the Canadian Geological Survey, and has made solid contributions of great value to Palæontology.

In requesting you, Lord Strathcona, as High Commissioner for Canada, to be so good as to transmit this Medal and its accompanying cheque to our esteemed

colleague in Ottawa, I would beg you at the same time to assure him that the Geological Society values his services to our science, takes an interest in his welfare, and sends its cordial wishes for the continued prosperity of the great scientific institution in which he has laboured so long, and to the renown of which he has so greatly contributed.

Lord Strathcona, in reply, expressed the pride and pleasure which he felt in receiving the medal on behalf of a palæontologist the great value of whose work had been known to him for many years. He recalled the inception of the Canadian Geological Survey under Sir William Logan, and remarked that in showing its appreciation of the merits of Dr. Whiteaves, one of the most indefatigable workers on that Survey, the Council of the Society had done honour to the Survey and to Canada.

The President then handed the Bigsby Medal, awarded to Mr. Arthur William Rogers, M.A., F.G.S., Director of the Geological Survey of Cape Colony, to Mr. G. W. Lamplugh for transmission to the recipient, addressing him as follows:—

Mr. Lamplugh,—The Bigsby Medal has been adjudicated by the Council to Mr. A. W. Rogers in appreciation of his important labours in South African Geology. For more than ten years he has been at work in Cape Colony, not infrequently under difficulties which, in older countries like our own, can hardly be realized. His numerous reports, whether prepared by himself alone or conjointly with his colleagues on the Geological Commission, and published in the Commission's annual volumes, have materially increased our knowledge of the geological structure of the southern part of the African continent. Besides these official memoirs, he has published alone, and also in conjunction with his able colleague Professor E. H. L. Schwarz, in the "Transactions of the South African Philosophical Society," some important papers in which striking evidence has been brought forward in favour of old glaciation during more than one geological period in South Africa. His volume published in London two years ago, under the title of "An Introduction to the Geology of Cape Colony," reveals the patient and cautious character of his work, and shows how firmly and quietly the foundations of our knowledge of the geological history of that interesting region are being laid.

This Medal is always given to one who is under 45 years of age, and thus, to use the words of its venerable founder, "probably not too old for further work, and not too young to have done much." In asking you to be so good as to transmit this award to Mr. Rogers, I should be glad if you would accompany it with an expression of our good wishes for himself, and of our continued interest in the important and useful work of the Geological Survey which he so ably superintends.

Mr. Lamplugh, in reply, said:—

Mr. President,—It gives me deep satisfaction to receive this Medal on behalf of Mr. Rogers, for, like all geologists who took part in the visit of the British Association to South Africa, I have learned to appreciate very highly the results of his work and to admire the patient sincerity of the worker.

Mr. Rogers has sent a letter which, Sir, with your permission, I will read:—

"Geological Commission, South African Museum, Cape Town, Jan. 15th, 1907.

"To the Council of the Geological Society of London.

"Gentlemen,—I thank you most heartily for the honour which you have done me by the award of the Bigsby Medal. I take it as a recognition that the Geological Survey of this Colony has been carried out on sound lines, and as an expression of your hope that the work will continue.

"The official geologists of the present generation in South Africa are more fortunate than their predecessors in having instructions which allow them to work steadily at the geological structure of the country, unhampered by frequent orders to investigate some local detail of passing interest. Thus a firm foundation is being laid for future work, both scientific and economic. In Cape Colony, which was the first of the South African countries to institute a systematic survey, the Geological Commissioners have pursued this policy from the commencement of the survey under their control; my predecessor in charge of the work, Dr. G. S. Corstorphine, always kept this end in view, and I have done the same.

"In examining the manuscript map (dated 1859) and sections made by the first official geologist at the Cape, Andrew Wyley, once a Fellow of this Society, it is impossible not to perceive that, had he been allowed to continue his work, the geology of the Colony would long ago have been well known, even as regards those parts where to-day the broad outlines are still uncertain.

"Circumstances prevent the establishment of a lavishly equipped Survey in this Colony, and there are many problems which have to be left almost untouched because their investigation requires too detailed work; but your award will make Cape geologists feel that their efforts are warmly appreciated, and I believe that my colleagues past and present will share my gratification.

"For myself, I must say that your generous gift will always urge me to do better work, and my only regret is that I am unable to receive the Medal personally from a man whose writings have been a constant source of instruction and pleasure to me ever since geology began to be the great interest of my life.—ARTHUR W. ROGERS."

In handing the Balance of the Proceeds of the Wollaston Donation Fund, awarded to Dr. Arthur Vaughan, B.A., to Professor W. W. Watts, for transmission to the recipient, the President addressed him in the following words:—

Professor Watts.—The Balance of the Proceeds of the Wollaston Donation Fund has been assigned to Dr. A. Vaughan, as a mark of the Council's appreciation of the excellence of his contributions to Geology, and in particular of his application of the zonal method of stratigraphical classification to the Carboniferous Limestone of this country. I had often wondered why this method, which was so successfully adopted many years ago for the corresponding portion of the Carboniferous system of Belgium, should never have been similarly applied to our own great Limestone deposit. Dr. Vaughan has now demonstrated, by a careful study of the corals and the brachiopods, how completely it is available here, and the basis of investigation which he has laid so firmly in the Bristol region will doubtless prove to be one upon which the stratigraphy of the Carboniferous Limestone throughout the rest of the British Isles may be satisfactorily worked out. When you transmit to him this award, will you assure him that the Society looks forward with much interest to the continuation of his important labours?

The President then presented the Balance of the Proceeds of the Murchison Geological Fund to Dr. Felix Oswald, addressing him as follows:—

Dr. Oswald.—The Council has awarded to you the Balance of the Proceeds of the Murchison Geological Fund, in recognition of the value of your contributions to our knowledge of the Geology of Armenia. The remarkable volume which you have published on this subject affords ample evidences of your keen powers of observation and of the indomitable courage with which you have done pioneer work in a little known country and with which, also, you have laid your results before the world.

Your treatise is, in one respect, probably unique in geological literature. To surmount the difficulties presented by the expense of publication, you purchased a hand-press, learned the art of type-setting, and laboriously printed off the whole book, page by page, with your own hand while the numerous sections, maps, and plates of fossils were likewise drawn, reproduced, coloured, and printed off by yourself. The volume is dedicated to your wife, who will share your pleasure at this recognition of your labours, and to whom with yourself I desire to convey the good wishes of the Geological Society.

In presenting a moiety of the Balance of the Proceeds of the Lyell Geological Fund to Mr. Thomas Crosbee Cantrill, B.Sc., the President addressed him in the following words:—

Mr. Cantrill.—The Council has this year awarded to you a moiety of the Balance of the Lyell Geological Fund in recognition of the quality of your contributions to Geology, more particularly in relation to the stratigraphy of the formations from the base of the Lias down into the older Palæozoic rocks. Your early paper on Wyre Forest afforded good promise of your future success. Since it appeared you have served for upwards of ten years on the Geological Survey, where, as I can personally

testify, your work has been characterized by remarkable carefulness and precision. It is to me a great gratification to hand this award to a former Survey colleague, and to wish you continued activity and success in your career.

The President then presented the other moiety of the Balance of the Proceeds of the Lyell Geological Fund to Mr. Thomas Sheppard, F.G.S., addressing him as follows:—

Mr. Sheppard,—The other moiety of the Balance of the Lyell Geological Fund has been assigned by the Council to you in acknowledgement of the useful additions made by you to our knowledge of the Pleistocene Geology of East Yorkshire; of the value of your bibliographical work and your labours in the Hull Museum; and of the excellence of your volume on "Geological Rambles in East Yorkshire," which contains much information presented by you in a popular and attractive form.

The President then proceeded to read his Anniversary Address, giving first of all obituary notices of several Fellows deceased since the last annual meeting, including Professor Eugène Renevier (elected Foreign Member in 1888), Professor S. L. Penfield (elected Foreign Correspondent in 1896), G. C. Churchill (elected a Fellow in 1864), the Rev. J. F. Blake (el. 1868), C. E. De Rance (el. 1869), R. P. Greg (el. 1853), J. G. Goodchild (el. 1884), Cav. W. P. Jervis (el. 1860), W. Cunnington (el. 1854), G. F. Harris (el. 1885), and P. Emary (el. 1897).

He then sketched out the arrangements contemplated for the celebration of the Society's Centenary. Enquiry had shown that the last week in the month of September appeared to be, on the whole, the time which would be most generally convenient to Fellows and guests in this country and to visitors from abroad. It was therefore intended that the celebration should take place at that time. Every Fellow of the Society would, of course, receive due notice, as well as a detailed statement of the arrangements when these had been finally settled. Invitations to attend the meetings would be immediately sent out to all the Foreign Members and Foreign Correspondents. Geological Societies, Geological Surveys, and learned institutions which had a geological side, would be asked to send delegates. Personal invitations would also be addressed to geologists of note in the Old and the New World who might not be already enrolled in the foreign lists of the Society. It was hoped that to these various invitations there would be a friendly response, either by personal representation or in writing. They might not impossibly be privileged to see a larger company of geologists assembled together in this country next September than had ever been gathered together here before.

It was thought that the official programme might extend over three days in London. The arrangements for each of these three days were under consideration; but he might mention now that he proposed to give his postponed address as the *pièce de résistance* of one of the forenoon or afternoon meetings. In that address he would offer a sketch of the state of geological science outside of Britain at the time when the Geological Society of London was founded, and indicate the external influences that affected its start. By this choice of a subject he hoped to interest the foreign guests, while at the same time inviting the Fellows of the Society into a domain of the history of science which was perhaps less familiar than it deserved to be.

The chronicle of the Society itself during the first hundred years of its existence had been carefully and fully compiled from all available sources by Mr. Horace B. Woodward, F.R.S. His volume was now in the printer's hands, and would be in the hands of Fellows in the course of the Summer.

Excursions to places of geological note in this country would probably be arranged, some to precede and others to follow the meeting in London. The various museums and places of interest in the Metropolis would, of course, be shown to the expected visitors; and there would doubtless be no lack of public and private hospitality. It was anticipated that the Universities of Oxford and Cambridge would both receive the foreign guests. But the details of these various arrangements had still to be worked out.

The ballot for the Council and Officers was taken, and the following were declared duly elected for the ensuing year:—*Council:* H. H. Arnold-Bemrose, J.P., M.A.; Professor S. H. Cox, F.C.S., Assoc. R.S.M.; Sir John Evans, K.C.B., D.C.L., LL.D., F.R.S., F.L.S.; Professor E. J. Garwood, M.A.; Sir Archibald Geikie, Sc.D., D.C.L., LL.D., Sec. R.S.; W. H. Hudleston, M.A., F.R.S., F.L.S.; F. L. Kitchin, M.A., Ph.D.; G. W. Lamplugh, F.R.S.; Professor C. Lapworth, M.Sc., LL.D., F.R.S.; R. Lydekker, B.A., F.R.S.; J. E. Marr, Sc.D., F.R.S.; H. W. Monckton, Treas. L.S.; F. W. Rudler, I.S.O.; Professor W. J. Sollas, Sc.D., LL.D., F.R.S.; L. J. Spencer, M.A.; A. Strahan, Sc.D., F.R.S.; C. Fox Strangways; J. J. H. Teall, M.A., D.Sc., F.R.S.; R. H. Tiddeman, M.A.; Professor W. W. Watts, M.A., M.Sc., F.R.S.; H. Woods, M.A.; A. Smith Woodward, LL.D., F.R.S., F.L.S.; and Horace B. Woodward, F.R.S.

Officers:—President: Sir Archibald Geikie, Sc.D., D.C.L., LL.D., Sec. R.S. *Vice-Presidents:* J. E. Marr, Sc.D., F.R.S.; Professor W. J. Sollas, Sc.D., LL.D., F.R.S.; Aubrey Strahan, Sc.D., F.R.S.; and J. J. H. Teall, M.A., D.Sc., F.R.S. *Secretaries:* Professor E. J. Garwood, M.A., and Professor W. W. Watts, M.A., M.Sc., F.R.S. *Foreign Secretary:* Sir John Evans, K.C.B., D.C.L., LL.D., F.R.S., F.L.S. *Treasurer:* Horace W. Monckton, Treas. L.S.

III.—February 27th, 1907.—Sir Archibald Geikie, Sc.D., D.C.L., LL.D., Sec. R.S., President, in the Chair.

The following communications were read:—

1. "On the Lower Ordovician Succession in Scandinavia." By William George Fearnsides, M.A., F.G.S.

The paper is a stratigraphical account of the *Dictyonema* Shales, the *Ceratopyge* Beds, the *Didymograptus* Shales, and the *Orthoceras* Limestone of Sweden and Southern Norway, and is based upon field observations of Scandinavian type localities made by the author during the Summer of 1906. The beds are discussed under the following headings:—

(C) *Didymograptus* Shales and *Orthoceras*kalk,
(B) Glauconite Shales and *Ceratopyge*kalk,
(A) *Dictyonema* and *Bryograptus* Shales,

which are found to be applicable to all the sections visited.

For purposes of ready correlation with the British Tremadoc rocks, the upper part of the *Acerocaris* zone of the Alum Shales is considered along with Division *A*, and the presence of trilobites of Ordovician type and related to those of the *Ceratopyge*kalk in that as well as in the *Dictyonema* Beds is emphasized. It is also held

that the branching graptolites of Division A show a progressive evolutional divergence from an original *Dictyonema* through *Dictyograptus flabelliformis* to the true graptolites of Clonograptid or Bryograptid types, and through *D. norvegicus* to the so-called 'dendroid graptolites.' The gradual replacement of the western type of Alum Shales of this division by the sandy beds with *Obolus* in Northern Öland and the Baltic Provinces is discussed, and is considered as an early manifestation of the crustal instability which brought about the curious vicissitudes of the Glauconite Shale period. Many of the phenomena at the base of Division B are suggestive of an unconformity; and in all Swedish areas except Skåne the succession from A to B is shown to be incomplete. In general, the base of Division B has much the aspect of the Cambridge Greensand, and the Glauconite Shales as a whole mark a period during which the alternating processes of deposition and erosion were nicely balanced. A curious small-scale erosion phenomenon occurring intermittently throughout Division B is redescribed under the name 'Korrosionsgrupper,' and along with the variable detailed succession of the beds is considered as a further proof of discontinuous sedimentation throughout the period. Division C of *Didymograptus* Shales and their equivalent *Orthoceras*-kalk is discussed only in outline. Both shales and limestone pass downwards continuously into the highest *Ceratopyge* Beds, both in lithology and fauna, and the difference between the lowest *Orthoceras* Limestone (Planilimbatenkalk) and the higher limestone of the *Ceratopyge*kalk is almost imperceptible.

This stratigraphical evidence is then considered in its bearing upon the question of the definition of the boundary between the Cambrian and the Ordovician Systems; and the author follows the Scandinavian authorities in considering that, so long as the *Dictyonema* horizon is available, the evidence of sudden faunistic change within the series discussed is too slight to warrant a palæontological separation of the systems at any other horizon. A comparison of the British Tremadoc and Arenig Series with these Scandinavian rocks concludes the paper; and it is maintained that the time has now arrived for British geologists to come into line with their Continental brethren, and to include the *Dictyonema* and the overlying Tremadoc Beds as the lowest series of the Ordovician System.

2. "The occurrence of Pseudomorphous Pebbles of Pyrites at the Crown Reef Mine (Witwatersrand)." By Cuthbert Baring Horwood, A.R.S.M., Assoc. M. Inst. C.E., F.G.S.

Reference is first made to the existence of calcite 'pebbles' in the Main Reef, which Mr. Julius Kuntz believes to be due to the replacement of quartz by calcite. Pellets of iron bisulphide known as 'buckshot' occur at the Rietfontein 'A' Mine in the Buckshot Reef: they exhibit radiate fibrous structure, and are probably of concretionary origin. At the Crown Reef Mine a few 'pebbles' of pyrites, some measuring as much as an inch in length, occur in a narrow band of conglomerate at the contact of the reef with a basic dyke. It is conjectured that the mineralising solutions which deposited the pyrites (together with some, if not all, of the

associated gold) ascended along the fractures due to the intrusion of the dyke, and found an easy course along the small conglomerate bed, where they replaced some of the quartz pebbles with pyrites, being kept up by a band of shale underneath the conglomerate.

IV.—March 13th, 1907.—Aubrey Strahan, Sc.D., F.R.S., Vice-President, in the Chair.

The following communications were read:—

1. "A Silurian Inlier in the Eastern Mendips." By Prof. Sidney Hugh Reynolds, M.A., F.G.S.

An account of the rocks with which the paper mainly deals was brought before the Society on February 7th, 1906 (see Abstract of Proc., Geol. Mag., 1906, p. 142); but, owing to the discovery just before the meeting of Silurian fossils in material thrown out by moles and rabbits, the paper was withdrawn and further work, including the digging of a series of seven trenches, was carried out. This proved that the fragmental igneous rock is of two types:—(1) Normal fine-grained tuff, from which in three localities over thirty species of Silurian (probably Llandovery) fossils were obtained and have been identified by Mr. F. R. Cowper Reed: the tuffs are seen at Sunnyhill to underlie the trap. (2) A remarkable coarse ashy conglomerate, the nature and relation of which to the other rocks are both obscure. The following four possibilities with regard to the nature of this rock are discussed in some detail:—(*a*) That it may be the basement conglomerate of the Old Red Sandstone; (*b*) that it may be an aqueous deposit of the same general age, and belonging to the same igneous series as the associated trap and normal tuff; (*c*) that it may be an old river-gravel, deposited during a terrestrial period subsequent to the fossiliferous Silurian and prior to the Old Red of the district; and (*d*) that it may represent the necks of the volcanoes from which the trap and the normal tuff were ejected. The author is of opinion that the fourth of these possibilities agrees best with the observed facts. The paper concludes with a comparison between the Mendip Silurian rocks and those of Gower and Tortworth, in both of which localities it appears that the upper beds of the Silurian System are unrepresented.

2. "On Changes of Physical Constants which take place in certain Minerals and Igneous Rocks on the Passage from the Crystalline to the Glassy State; with a short Note on Eutectic Mixtures." By James Archibald Douglas, B.A., F.G.S.

After giving an account of previous experiments in the direction of determining the physical changes accompanying the fusion of rocks and minerals, and their re-solidification into a glassy condition—experiments which are in many cases open to sources of considerable error—the author describes the electrical apparatus employed by himself. Powdered rock of known specific gravity is fused as often as required in a loop of platinum-ribbon. The fused product is powdered, examined with the microscope, and then placed in a diffusion-column, by the use of which errors due to the few small

bubbles or unfused mineral particles, on the few occasions when these exist, are eliminated. The diffusion-column is sealed in a glass tube. Acid rocks were found to increase 6 to 10 per cent. in volume, intermediate rocks 5 to 7 per cent., and basic rocks chiefly less than 6 per cent. Of the minerals tested, pargasite underwent the greatest expansion, albite gained 10 per cent., while in anorthite and leucite the increase was less than 4 per cent. It is pointed out that this expansion would be a very effective force in the case of the melting of rock-magmas kept solid by pressure. Experiments were also made in order to ascertain the melting-points of the rocks and minerals experimented upon: these were found to range from 1260° C. for rhyolite to 1070° C. for Clee Hill dolerite. The refractive indices of the glasses were determined in dense fluids. In determining the melting-points of individual minerals, the author's results agree fairly closely with those of Day & Allan, but differ from those of Joly & Cusack. An attempt was made to find experimentally the eutectic proportions of quartz and felspar. It was found impossible to reproduce in the laboratory the conditions which, in nature, seem to have existed during the formation of pegmatites. On the other hand, a mixture of orthoclase and albite gave a melting-point lower than those of either mineral taken separately.

V.—Mineralogical Society.

Tuesday, January 29th.—Professor H. A. Miers, F.R.S., President, in the Chair.

Experiments bearing on the order of crystallisation of Rock-constituents, by Professor H. A. Miers. The general results of experiments made by Miss F. Isaac and Professor Miers with mixtures of salol and betol in all proportions were described: the experiments have established the supersolubility curves even beyond the points where they cross below the eutectic temperature. Owing to the fact that the main separation of crystals in the cooling mixtures takes place only when the liquids have been supercooled to temperatures given by the supersolubility curves, it has been found (1) that in general the mixtures do not solidify as a eutectic mixture, (2) that according to the conditions of supercooling either substance could be made to crystallise before the other in mixtures approaching the eutectic in composition. It was suggested that these results are applicable to the solidification of many rocks and alloys.—Serpentine Rock from the Tarnthaler Köpfe, Tyrol, by Dr. A. P. Young. The minerals found in the serpentine are diopside, tremolite, clinochlore, picotite, magnetite, iron pyrites, and a fibrous mineral referred to antigorite. The latter mineral is regarded as holding a place between the micas and chlorites. On the surface of the serpentine are projecting bastite pseudomorphs coated with films of silvery lustre. The serpentine is a non-foliated intrusive core, which on the borders is highly foliated and passes into talc-bearing phyllites.—A simple tabular arrangement of the 32 crystallographic classes, by Dr. J. W. Evans. The table is based on the character of the symmetry of the principal zone axis or zone axes. Each column contains classes with

the same rotational symmetry round the axis, and each row those which agree in the other symmetrical characters of the axis.—A new model of crystal-refractometer, by Dr. G. F. Herbert Smith. This instrument is identical in principle with that previously described, and is intended for use with large mineral specimens and mounted gem-stones. No part extends above the level of the plate holding the dense-glass hemisphere. Further, the optical combination has double the focal length of the earlier form and provides consequently greater refinement.—Isomorphism as illustrated by certain varieties of magnetite, by Professor B. J. Harrington. Analyses are given of specimens of magnetite from St. Joseph du Lac, Canada, and from Magnet Cove, Arkansas, both showing the unusual combination of octahedron and trapezohedron {311}. The Canadian specimen contained about 5 per cent. of TiO_2, 8 per cent. of MnO, and 3 per cent. of MgO; and the specimen from Arkansas about 10 per cent. of Al_2O_3, 2 per cent. of TiO_2, 2 per cent. of MnO, and 9 per cent. of MgO.—Mr. Fleischmann exhibited a collection of zeolites from Japan, Dr. Evans an objective giving a flat field with convergent light, and Professor Miers a goniometer to be used for the measurement of the refractive indices of cooling solutions, for which purpose it is provided with means for maintaining a constant temperature for any desired period.

VI.—Palæontographical Society.

The sixtieth Annual Meeting of the Palæontographical Society was held at the apartments of the Geological Society, Burlington House, on March 16th, Dr. Henry Woodward, F.R.S., President, in the chair. The report of the Council congratulated the Society on its continued prosperity, and the value and variety of the Monographs which it still received for publication. The funds had been augmented by a special sale of back stock to members, but the normal income showed a gradual decline owing to the difficulty of obtaining new personal subscribers to replace those lost by death. The Carnegie Trust for the Universities of Scotland paid for the production of five plates of Old Red Sandstone Fishes illustrating Dr. Traquair's Monograph issued in 1906. The Rev. J. F. Blake, Mr. Thomas Leighton, and Miss Caroline Birley were among the members deceased since the last annual meeting. Dr. Henry Woodward, Dr. G. J. Hinde, and Dr. A. S. Woodward were re-elected President, Treasurer, and Secretary respectively. Messrs. J. Hopkinson, W. D. Lang, H. Woods, and G. W. Young were elected new members of Council.

VII.—Zoological Society.

At the meeting of the Zoological Society on March 19th, 1907, Mr. H. F. Standing, M.Sc., exhibited and described a large series of remains of comparatively gigantic extinct lemurs, which he had discovered in a marsh in Madagascar. He arrived at the following general conclusions as to the relationships of these animals and the Prosimiæ in general:—

1. The recent Indrisinæ *Chiromys*, *Mesopropithecus*, *Palæopropithecus*, *Archæolemur*, and *Hadropithecus* are all more or less specialized representatives of one common Prosimian stock.

2. Specialization has taken place in various directions and to very varying degrees among the different genera enumerated; *Archæolemur*, *Hadropithecus*, and *Mesopropithecus* retaining on the whole the greatest number of pithecoid characters.

3. Even the least specialized forms have undergone retrogressive changes as compared with the ancestral Tertiary stock from which they, in common with the extant Indrisinæ, are derived. This is notably true as regards the condition of the frontal region of the brain.

4. A comparison of the least specialized members of this Indrisine group of Prosimiæ with the various families of the Old and New World Monkeys, shows in several characters closer affinities with the latter than with the former (e.g., auditory bullæ, traces of primitive dentition, procumbent lower incisors, tendency to lose third molar, platyrhine condition of nasals).

5. A comparison of the Malagasy Lemurinæ, recent and sub-fossil, with the various genera of the Indrisine group supports the belief that retrogressive specialization has proceeded even further in their case than in that of the recent Indrisinæ. This retrogressive specialization has in general proceeded on similar lines in the two groups, though the deviations from the primitive dental formula are less pronounced among the Lemurine than among the Indrisine genera.

6. The members of the family of the Lemuridæ outside of Madagascar are found in scattered groups over a wide area in the Old World and bear the marks of a decadent group. All are nocturnal, and many are curiously specialized.

7. A comparison of the various genera of Lemuridæ with one another and with the New World Monkeys, both recent and fossil, leads to a strong presumption that these families as well as the Malagasy Indrisine group have had a common origin.

8. In view of the recent additions to our knowledge of the Prosimiæ and of their close relations to the Apes, it seems no longer necessary, or indeed possible, to separate the Primates into the two suborders of Lemuroidea and Anthropoidea.

Most of the specimens described by Mr. Standing belong to the Malagasy Academy, Antananarivo, but a typical and extensive selection has been acquired by the British Museum (Natural History).

CORRESPONDENCE.

MARINE RIPPLE-MARK.

Sir, — In your issue for February, p. 96, your correspondent Mr. A. R. Hunt quotes one among the many experiments I showed in my lecture to Section G at Cambridge, and deduces from it that my "results and conclusions . . . . . have practically no bearing on the phenomena of the sea-shore and sea-bottom."

Even had I shown only this one experiment, such a statement would surely have been somewhat sweeping; but as I actually